



SOUTH FLORIDA ECOSYSTEM RESTORATION TASK FORCE

LEADERSHIP • PARTNERSHIP • RESULTS

SYSTEM-WIDE ECOLOGICAL INDICATORS FOR EVERGLADES RESTORATION 2020

EVERGLADESRESTORATION.GOV
Restoring America's Everglades

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EXECUTIVE SUMMARY

This report is a digest of scientific findings about eleven system-wide ecological indicators in the South Florida Ecosystem (Table 1). These eleven indicators have been carefully selected in order to focus our ability to assess the success of the Everglades restoration program from a system-wide perspective.

Table 1. System-wide Ecological Indicators

- Invasive Exotic Plants
- Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation
- Eastern Oysters
- Crocodilians (American Alligators & Crocodiles)
- Fish & Macroinvertebrates
- Periphyton
- Wading Birds (White Ibis & Wood Stork)
- Southern Coastal Systems Phytoplankton Blooms
- Florida Bay Submersed Aquatic Vegetation
- Juvenile Pink Shrimp
- Wading Birds (Roseate Spoonbill)

These indicators are key organisms that we know (through research and monitoring) respond to environmental conditions in ways that allow us to measure their responses in relation to restoration activities. Because of this, we may see similar ecological responses among indicators. This logical agreement among indicators - a collective response, if you will - can help us understand how drivers and stressors act on more than one indicator and provides a better system-wide awareness of the overall status of restoration as reflected in the ecological responses of these indicators. The more indicators that collectively respond to the drivers and stressors, the stronger the signal that the underlying problem is ubiquitous to the system and is affecting the fundamental ecological and biological nature of the Everglades ecosystem. Fixing these problems is key to fixing the Everglades.

The big picture findings below stem from these collective responses and are the findings that were common to more than one indicator, and to large, important regions of the natural system.

- **System-wide status of none of the indicators has changed over this reporting period and none have met system-wide restoration targets.** This is not surprising since projects that will contribute the greatest benefits to these indicators have not yet been implemented. Of the eleven indicators seven are red indicating well below restoration targets {Lake Okeechobee nearshore zone submersed aquatic vegetation, Eastern oyster, crocodilians, fish & macroinvertebrates, wading birds (white ibis & wood stork), southwest coastal systems phytoplankton blooms, and wading birds (roseate spoonbill)}, three are yellow, (invasive exotic plants, periphyton, Florida Bay submersed aquatic vegetation) and monitoring for one (pink shrimp) is no longer adequate to provide a system-wide stoplight color. These results reflect that current ecological conditions are close to the tolerance for many of the indicators and emphasize the importance and urgency of restoration efforts.
- **Long-term tracking of these indicators has provided us information that supports our general hypotheses that more water within the central Everglades resulting in greater freshwater flows to Florida Bay is beneficial.** Exceptional rainfall and ideal

EXECUTIVE SUMMARY

water levels in the spring of 2018 resulted in record nesting for wading birds, strongly suggesting that restored flows and hydroperiods will result in larger nesting numbers and increased nesting success. In addition, this wetter period aided the recovery of seagrass in Florida Bay supporting the benefit of more freshwater flows to Florida Bay. In contrast, the less than optimal hydrological conditions in WY 2019 and WY 2020 resulted in low wading bird nesting numbers and late nesting.

- **Invasive exotic plants and animals continue to present challenges to Everglades restoration.** While large portions of the restoration footprint have been cleared and maintained at low infestation levels, the overall geographic distribution of many invasive plant species has increased and in some areas populations previously under control have resurged, largely due to inadequate resources for management. Repeated follow up treatments are required to reach maintenance control. This is possible as is illustrated in WCA 2B, which once had very large melaleuca infestations, and many wondered if the plant could ever be sufficiently controlled there. The melaleuca strategy that relied on integrative pest management, consistent and sufficient management funding, monitoring, regulatory and research caused WCA 2B to finally go green.
- **Although concentrations have been reduced substantially, phosphorus (P) continues to be a system-wide water quality concern.** Elevated concentrations complicate water management operations and legal constraints and, as such, can constrain the ability to supply more water to the natural system. On a system-wide scale the periphyton indicator remains below the restoration target in central and northern WCA-3A and WCA-2A because these areas have not recovered from a history of higher than ambient phosphorus loading and have not received the benefits of restoration projects that have not yet been implemented. Downstream/coastal regions of Everglades National Park are below the restoration target because they are receiving increasing amounts of marine-sourced phosphorus in the absence of full-scale Everglades Restoration implementation.
- **Monitoring programs continue to have funding challenges that affect system-wide reporting.** Budget constraints, flat budgets, and inflation are eroding the ability to maintain comprehensive system-wide monitoring, synthesize the information, and provide timely reporting. Five of the eleven indicators have had modifications to reporting to take into account reductions in sampling due to budgets. Others may have to do the same as funding amounts have not maintained pace with inflation. As more projects come on-line we will only be able to see system-wide benefits IF appropriate monitoring is in place. Project level monitoring will be important for assessing benefits of individual projects and can be integrated with system-wide monitoring but is not a substitute for it.
- **COVID-19 affected sampling** or data analysis for Invasive exotic plants, crocodilians, periphyton, and fish and macroinvertebrates because of restrictions on conducting field work or access to laboratories for processing samples. Therefore, some of the spotlight values are for WY 2019 rather than WY 2020.

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What are ecological indicators and why do we need them?

“An ecological indicator is a metric that is designed to inform us easily and quickly about the conditions of an ecosystem.” (Bennett 2000)

“A useful ecological indicator must produce results that are clearly understood and accepted by scientists, policy makers, and the public.” (Jackson et al. 2000)

Ecological indicators are used to communicate information about ecosystems and the impact human activity has on them. Ecosystems are complex and ecological indicators can help describe them in simpler terms. For example, the total number of different fish species found in an area can be used as an indicator of biodiversity.

There are many different types of indicators. They can be used to reflect a variety of aspects of ecosystems, including biological, chemical, and physical. Due to this diversity, the development and selection of ecological indicators is a complex process.

National indicators for pollution (for example the ozone index one sees on the daily news) and the economy (for example the gross domestic product reported daily in the news as the measure of national income and output) have been used for decades to convey complex scientific and economic principles and data into easily understandable concepts.

Many ecological restoration initiatives globally and nationally are either currently using or developing ecological indicators to assist them in grading ecological conditions. A few of the larger US restoration programs that are developing and using ecological indicators include Chesapeake Bay, Maryland; San Francisco Bay Delta River System, California; Yellowstone National Park, Montana; Columbia River, Oregon; and the South Florida Ecosystem restoration program.

Indicators make understanding an ecosystem possible in terms of management, time, and costs. For example, it would be far too expensive, perhaps even impossible, to count every animal and plant in the Everglades to see if the restoration was a success. Instead, a few indicator species can be monitored in a relatively few locations to determine the success of the restoration. Indicators can be developed to evaluate very specific things or regions, or to evaluate broad system-wide aspects of an ecosystem.

This report is a digest of scientific findings about eleven system-wide ecological indicators in the South Florida Ecosystem (Table 1). These eleven indicators have been carefully selected in order to focus our ability to assess the success of the Everglades restoration program from a system-wide perspective.

These ecological indicators are organisms that integrate innumerable ecological functions in their life processes. For example, hydrology (water depth, timing, and duration) and water quality affect the types and quantities of periphyton, which affect the types and quantities and availability of fish that feed on periphyton, which affect the amount and availability of fish as food for alligators and wading birds. They're all interconnected, and indicators provide a more pragmatic means to understand those complex interconnections.

Ecological indicators are used because we cannot measure everything all the time. Scientists measure a few attributes of a few indicators precisely because they integrate many ecological and biological functions that either we cannot measure because it would be too expensive and time consuming, or simply because some things are too difficult to measure. Thus—through measuring more simple aspects of the lives of key organisms—we are able to take into account the innumerable biogeochemical and environmental processes they integrate and, through more

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simple and affordable research and monitoring, we can begin to understand how indicators may respond to ecosystem drivers and stressors such as rainfall, hydrology, salinity, water management, nutrients, and invasive exotic species.

Purpose

This suite of system-wide ecological indicators has been developed specifically to provide a mountaintop view of restoration for the South Florida Ecosystem Restoration Task Force (Task Force) and Congress.

The Task Force, established by section 528(f) of the Water Resources Development Act (WRDA) of 1996, consists of 14 members. There are seven federal, two tribal, and five state and local government representatives. The main duty of the Task Force is to provide a coordinating organization to help harmonize the activities of the agencies involved with Everglades restoration. The Task Force requested that the Science Coordination Group (SCG, a team of scientists and managers) develop a small set of system-wide ecological indicators that would help them understand, in the broadest terms, how the ecosystem and key components are responding to restoration and management activities via implementation of the Comprehensive Everglades Restoration Program (CERP) and other non-CERP restoration projects.

The CERP and REstoration, COordination, and VERification (RECOVER) programs were developed to monitor many additional aspects of the ecosystem, including such things as: rare and endangered species, mercury, water levels, water flows, stormwater releases, dissolved oxygen, soil accretion and loss, phosphorus concentrations in soil and water, algal blooms in Lake Okeechobee, hydrologic sheet flow, increased spatial extent of flooded areas through land purchases, percent of landscape inundated, tree islands, salinity, and many more. The set of indicators included here are a subset from those larger monitoring and assessment programs. They are intended to provide a system-wide, big-picture appraisal of restoration. Many additional indicators have been established that provide a broader array of parameters. Some of these are intended to evaluate sub-regional elements of the ecosystem (e.g., individual habitat types), and others are designed to evaluate individual CERP projects (e.g., water treatment areas). This combination of indicators affords managers information for adjusting restoration activities at both large and small scales.

Goal

Any method of communicating complex scientific issues and findings to non-scientists must: 1) be developed with consideration for the specific audience, 2) be transparent as to how the science was used to generate the summary findings, 3) be reasonably easy to follow the simplified results back through the analyses and data to see a clear and unambiguous connection to the information used to roll -up the results, 4) maintain the credibility of the scientific results without either minimizing or distorting the science, and 5) should not be, or appear to be, simply a judgment call (Norton 1998, Dale and Beyeler 2001, Niemi and McDonald 2004, Dennison et al. 2007). In reviewing the literature on communicating science to non-scientists we realized that the system of communication we developed for this suite of system-wide ecological indicators must be effective in quickly and accurately getting the point across to our audience in order for our information to be used effectively (Rowan 1991, 1992, Dunwoody 1992, Weigold 2001, Thomas et al. 2006, Dennison et al. 2007).

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The approach we used to select these indicators focused on individual indicators that integrated numerous physical, biological, and ecological properties, scales, processes, and interactions to try to capture that sweeping mountaintop view. Based on the available science, we made the underlying assumption that these indicators integrated many additional ecological and biological functions that were not or could not be measured and thus provided an assessment of innumerable ecological components that these indicators integrated in their life processes.

Having too many indicators is recognized as one of the more important problems with using and communicating them (National Research Council 2000, Parrish et al. 2003). Identifying a limited number of focal conservation targets and their key ecological attributes improves the successful use and interpretation of ecological information for managers and policy makers and enhances decision making (Schiller et al. 2001, Parrish et al. 2003, Dennison et al. 2007).

Our goal has been to develop and use a suite of indicators composed of an elegant few that would achieve a balance among: feasibility of collecting information, sufficient and suitable information to accurately assess ecological conditions, and relevance for communicating the information in an effective, credible, and persuasive manner to decision makers. For the purposes of this set of indicators, "system-wide" is characterized by both the physiographic and ecological elements that include: the boundary of the South Florida Water Management District (SFWMD) and RECOVER assessment modules (Figure 1) and the ecological links among key organisms [see Wetlands 25:4 (2005) for examples of the Conceptual Ecological Models (CEM)].

In addition, these indicators will help evaluate the ecological changes resulting from the implementation of the restoration projects and provide information and context by which to adapt and improve, add, replace, or remove indicators as new scientific information and findings become available. Indicator responses will also help determine appropriate system operations necessary to attain structural and functional goals for multiple habitat types among varying components of the Everglades system.

Using a suite of system-wide ecological indicators to present highly aggregated ecological information requires indicators that cover the spatial and temporal scales and features of the ecosystem they are intended to represent and characterize (Table 2; Figure 2). While individual indicators can help decision makers adaptively manage at the local scale or for particular restoration projects, collectively, indicators can help decision makers assess restoration at the system scale.

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Table 2. List of South Florida Ecosystem Features Landscape Characteristics

Hydropatterns

- Hydroperiods
- Vegetation Pattern and Patchiness
- Productivity
- Native Biodiversity
- Oligotrophy (low in nutrients)
- Pristine-ness
- Intactness (connectivity/spatial extent)
- Trophic Balance
- Habitat Balance/Heterogeneity

Trophic Constituents and Biodiversity

- Primary Producers (autotrophs - organisms that obtain energy from light or inorganic compounds; and detritus - dead organic material) Primary Consumers (herbivores and detritivores - animals that eat plants or detritus)
- Secondary Consumers (animals that feed upon herbivores and detritivores)
- Tertiary Consumers (animals that feed upon secondary consumers)

Physical Properties

- Water Quality
- Water Management (i.e., when, where, and how much water is moved)
- Invasive Exotic Species
- Salinity
- Nutrients (e.g., Nitrogen, Phosphorus, Sulphur)
- Contaminants (e.g., pesticides, pharmaceutical chemicals, mercury)
- Soils

Ecological Regions (see Figure 1)

- Greater Everglades
- Southern Coastal System
- Northern Estuaries
- Big Cypress
- Kissimmee River Basin
- Lake Okeechobee
- Florida Keys

Temporal Scales (see Figure 2)

- Indicators that respond rapidly to environmental changes (e.g., periphyton)
- Indicators that respond more slowly to environmental changes (e.g., crocodilians)

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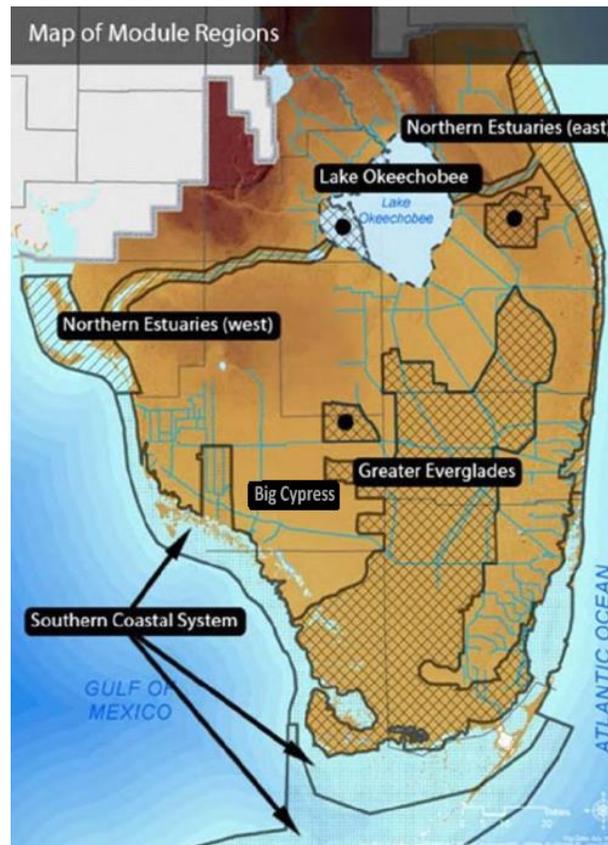


Figure 1. Map of south Florida illustrating the boundaries of the RECOVER regional assessment modules (black lines and cross hatching). Figure courtesy of RECOVER's 2009 System Status Report.

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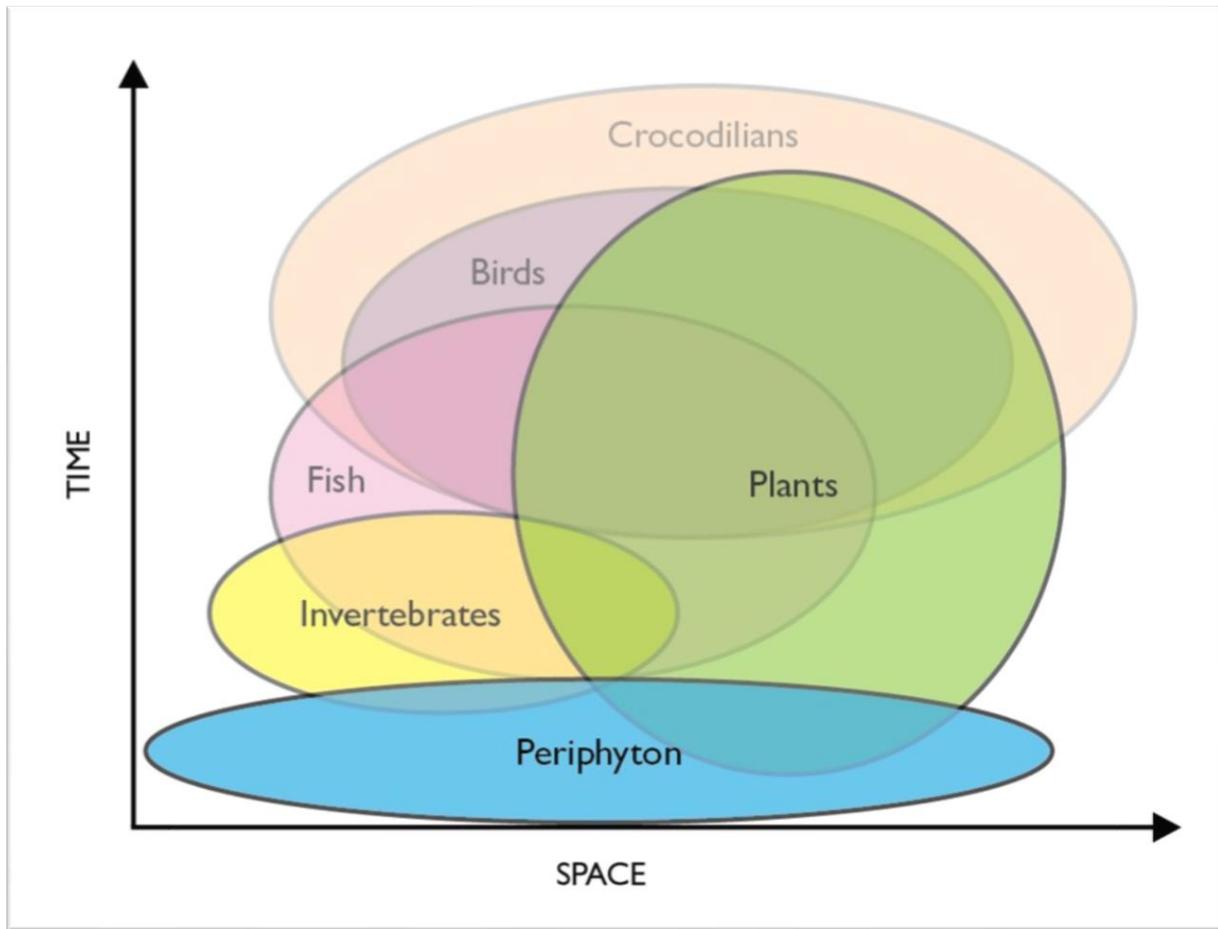


Figure 2. Graphical representation of how the individual indicators (only 6 indicators are shown interrelate with the temporal and spatial aspects of the ecosystem). The suite of system-wide ecological indicators was chosen based upon their collective ability to comprehensively reflect ecosystem response in terms of space and time. For example, periphyton responds to change very rapidly at both small and large spatial scales while crocodilians respond more slowly to change at small to large spatial scales. As indicators, they “cover” different aspects of the ecosystem. The system-wide ecological indicators collectively “cover” the ecosystem in terms of response to change over space and time. This figure is an illustration of how individual indicators may interrelate and respond to restoration in terms of space and time. This figure uses six indicators as an example and is not meant to precisely represent the exact spatial and temporal interactions of the system-wide ecological indicators.

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We chose stoplights to depict indicator status. There are many different methods that are being used to communicate scientific information in easier-to-understand formats. We evaluated numerous methods and ideas on organizing and communicating complex science and found many helpful ideas. We also noted that most methods were, in the end, still quite complex, and it took more information and explanation to understand the method than we felt made sense if the goal was to make things easier to understand. Therefore, we chose to use one of the most clear-cut and universally understood symbols—the stoplight—with a simple and straightforward findings page to provide a reasonable context for the stoplights.

Details of how stoplight colors are assigned for each indicator are available in a special issue of *Ecological Indicators* (2009, V9 Supplement 6). In this 2018 report, additional information on indicator calculations is provided to reflect information learned and changes in sampling.

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HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL INDICATORS: WATER YEARS 2018-2020

Hydrology is a major driver of Everglades ecology. In this section we provide an overview of the south Florida water cycle and a basic description of conditions during the reporting period: Water Years (WY) 2019 (May 1, 2018 to April 30, 2019) and 2020 (May 1, 2019 to April 30, 2020).

The Everglades has a hydrologic cycle, also called a water cycle, uniquely its own. Throughout most of the continental United States to the north, water levels generally rise and fall in tune with the four seasons. There, water levels typically peak during the spring as snow melts and front-driven storms move through, and ebb in the fall at the end of the hot summer stretch. The water cycle of subtropical south Florida and the Everglades, however, is fueled by only two seasons, wet and dry, leading to a reversal of its seasonal high and low water marks. In contrast with conditions to the north, water levels in the Everglades peak in the fall, coinciding with the end of the wet season, and ebb in the spring, coinciding with the end of the dry season when large expanses of wetlands dry out (Figure 3).

Although south Florida is generally considered a wet region (with an average annual rainfall of approximately 52 inches), serious droughts are common because of both longer-term climate variations and the seasonal pattern of rainfall. On average, approximately 77% (or 40 inches) of the total annual rainfall occurs in the May through October wet season, while approximately 23% (or 12 inches) occurs in the November through April dry season (Figure 4).

Historically, prolonged drought cycles are broken by periods of increased tropical cyclone activity (tropical depressions, tropical storms, and hurricanes). In addition, large-scale climate drivers also have a significant impact on south Florida hydrology. The hydrologic conditions during WY 2016 was highly influenced by the El Niño-Southern Oscillation (ENSO), a climatic phenomenon caused by warming sea surface temperatures in the eastern Pacific, which strongly influences dry season rainfall variability in south Florida.

El Niño years have warmer Pacific sea surface temperatures, which translates into above average rainfall and surface water flows during the south Florida dry season. By contrast, La Niña years are associated with cooling Pacific sea surface temperatures, and conversely, dry season rainfall and water flows tend to be below average. Unlike WY 2016 that was strongly influenced by El Niño, neutral to slightly La Niña trending conditions persisted throughout Water Years 2019 and 2020 (Figure 5).

Summer Wet Season

The wet season begins in late spring, usually around Memorial Day. It is characterized by consistently hot and humid weather, the daily buildup of spectacular cumulonimbus cloud formations, and resultant heavy thunderstorms that are often local and short-term in nature. Other larger systems—including early season storms enhanced by lingering spring-time instability in the upper atmosphere, mid-latitude cyclones, and tropical storms—periodically spike the Everglades with regionally expansive rains.

In response to these meteorological inputs, the Everglades become flooded with an ankle- to waist-deep, slow-moving pool of water through summer and fall, leaving only the high-ground tree islands and hardwood hammocks above water.

HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL INDICATORS: WATER YEARS 2018-2020

The term sheet flow is used to describe this shallow and spatially expansive wetland plain that, unlike a lake or bog, flows like a stream, only much more slowly, almost imperceptibly slowly to the human eye. Spanning from horizon to horizon, this sheet of water flows south through a maze of tree-island-dotted ridges and sinuous low-lying sloughs, giving rise to the name River of Grass coined by Marjory Stoneman Douglas in 1947.

Winter Dry Season

The weather turns mild during the winter half of the year, marking an end to the regular buildup of afternoon thundershowers and tropical storms and thus initiating the dry season, an approximate 6- to 7-month period dominated by a slow shallowing of standing water. As the dry season ensues, more and more land emerges. Water first recedes from the highest perched pinelands and other tree islands. Drainage of the marl prairies follows next, leading to an eventual retreat of water into the lowest-lying sloughs and marshes. The rate of recession may be slowed or even temporarily reversed by sporadic winter rains that are typically brought on by the descent of cold continental air masses from the north. Lower winter evaporation rates also hinder the rate of recession, though it rapidly picks up again in the spring as daylight hours and air temperatures increase evaporation.

Although south Florida is generally considered a wet area by merit of its abundant average annual rain total of 52 inches (with a 70/30 percent wet/dry season split) and its often flooded wetland views, drought and wildfire play vital roles in maintaining the region's unique assemblage of flora and fauna. The ecological health of the Everglades is intimately tied to seasonal and inter-annual fluctuations of the water cycle and is impacted by a combination of:

- Natural processes
 - Rainfall
 - Evaporation
 - Overland flow
 - Groundwater infiltration
 - Wildland fire
- Climatic oscillations
 - El Niño/La Niña
 - Climate change
- Water management manipulation associated with operation of the Central and Southern Florida (C&SF) project and other drainage works for the purpose of:
 - Flood protection
 - Urban and agricultural water supply
 - Environmental protection

Each water year is different in the Everglades, and the hydrologic cycle is characterized by large inter-annual variation – in other words, seldom do we experience average years. The previous two water years illustrate this variation well and are summarized next.

HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL INDICATORS: WATER YEARS 2018-2020

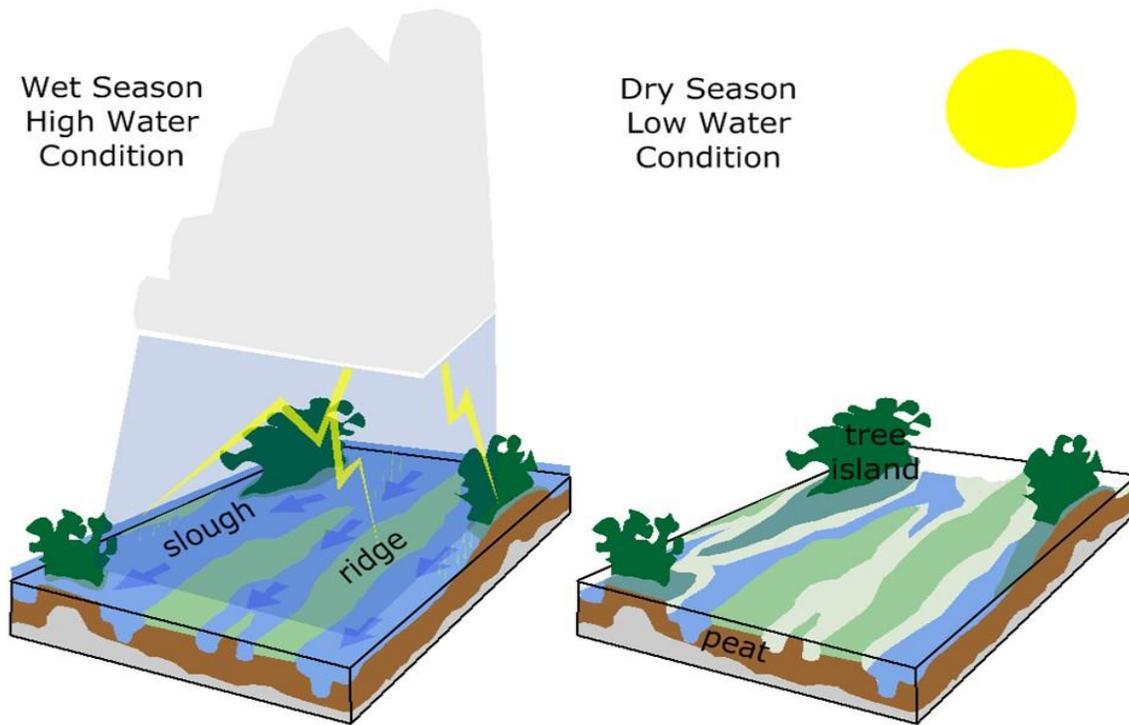


Figure 3. Artistic representations of the Everglades during fall high water and spring low water conditions. During the summer/fall rainy season, a shallow and slow-moving sheet of water inundates the entire ridge and slough landscape (except for the tree islands that usually remain dry). During the winter/spring dry season, water levels drop to the point that only the sloughs usually hold water.

HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL
INDICATORS: WATER YEARS 2018-2020

Water Year Rainfall Totals For South Florida, 1980-2020

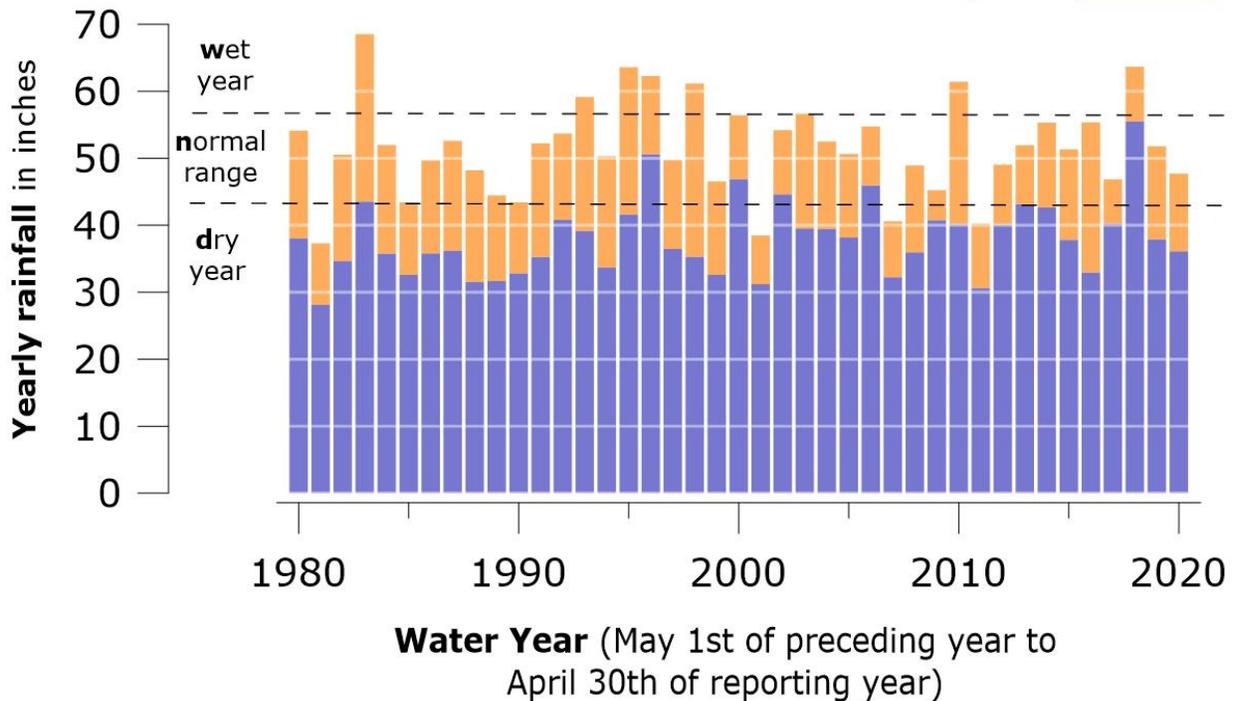


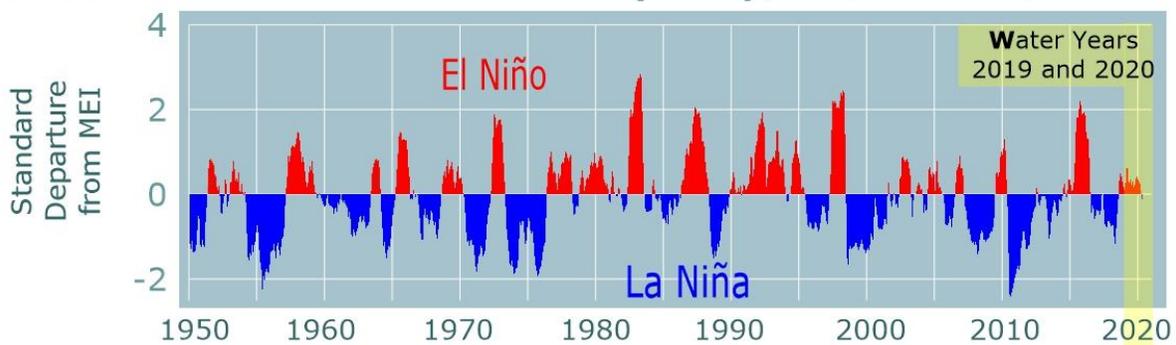
Figure 4. Yearly rainfall (inches) throughout the SFWMD. This graph was produced using daily rainfall data provided by the SFWMD. District meteorologists compute a daily rainfall value for the fourteen major basins and district-wide from rain gauge measurements. See www.Gohydrology.org for more information.

HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL INDICATORS: WATER YEARS 2018-2020



Comparison of South Florida's Dry Season Rainfall and the El Niño Southern Oscillation (ENSO) Index

Multivariate ENSO Index (MEI), as provided by NOAA



Dry Season Rain, as deviation from 14 inch Nov-Apr average

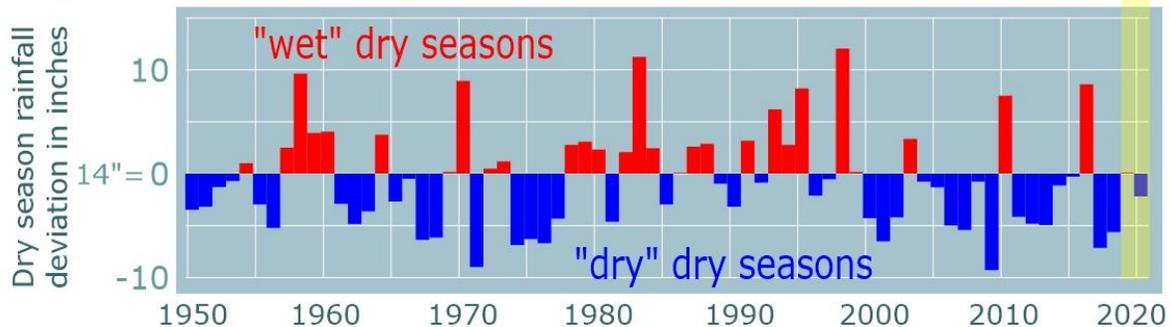


Figure 5. Correlation between the Multivariate ENSO Index (MEI) and winter dry season rain totals for south Florida. The top graph displays the standard departure of the MEI from 1950 to present. The bottom graph shows dry season rainfall for south Florida expressed as a departure (in inches) from the 14-inch November through April long-term average. In general, dry season rain totals are amplified during El Niño events and diminished during La Niña events.

HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL INDICATORS: WATER YEARS 2018-2020

Monthly Rainfall in South Florida for Water Years 2019 and 2020

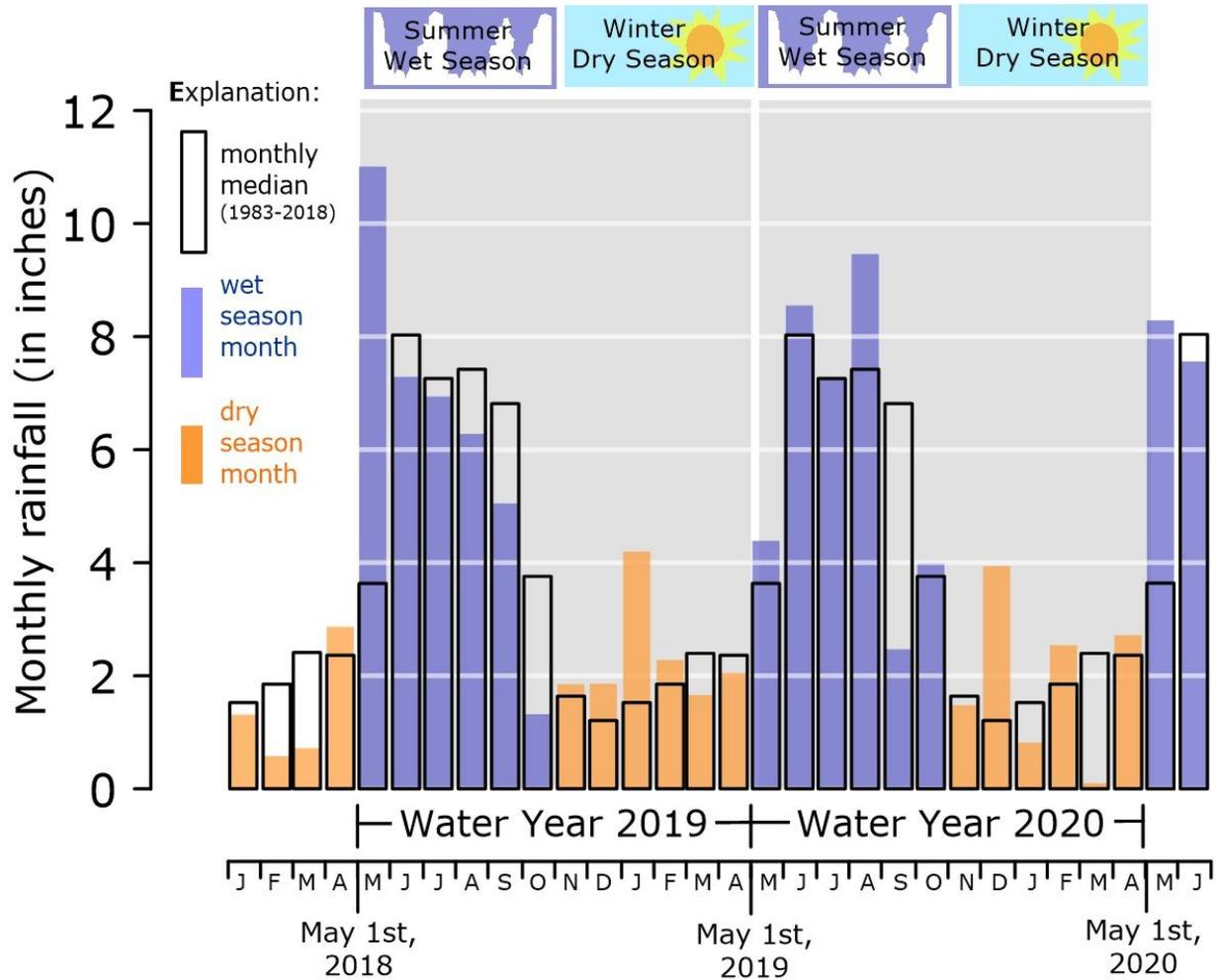


Figure 6. Summary of monthly rainfall in Water Years 2019 and 2020 throughout the South Florida Ecosystem. The graph was produced using daily rainfall data provided by the SFWMD. SFWMD meteorologists compute a daily rainfall value for the fourteen major basins and district-wide from rain gauge measurements. See <http://www.gohydrology.org/p/about.html> for more information.

HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL INDICATORS: WATER YEARS 2018-2020

Water Year Summaries

Water Year 2019 (May 1, 2018 to April 30, 2019)

WY 2019 started with prodigious rains in the May, the wet season's opening month. Usually a time of transition when both the water table bottoms out and the regular pattern of afternoon thunderstorms begins—resulting in the gradual rise of the water through the Everglades and Big Cypress Swamp. The triple dose of May's usual rainfall allotment (Figure 6) quickly jumped the water table up into the cypress and sawgrass plains. In response, water depths in May 2018 were higher than average in the Water Conservation Areas and Everglades National Park, but still drier in the Big Cypress (Figure 7, upper maps). Initial expectations of a flood year resembling the Hurricane-Irma fueled 2017 wet season failed to materialize as summer rains fizzled early, recording only six inches of combined rainfall in September and October compared to the normal 12 inches. In response, water depths in October 2018 were lower than average in the Water Conservation Areas and the Big Cypress (Figure 7, lower maps), leading to an early start to the dry season. Surface water had all but disappeared from much of the Water Conservation Areas and the Big Cypress Swamp by January, setting the stage for a deep and prolonged dry season, when a series of storms flooded the cypress back to July levels.

WY 2019 exemplified the seasonally predictable, yet mercurial, nature of the south Florida weather cycle. What was expected to be a “wet” wet season turned dry, and what looked to be a “dry” dry season turned wet. Shifts between flood and drought can occur quickly both within and during the transition between the approximate 6-month long wet and dry seasons.

Water Year 2020 (May 1, 2019 to April 30, 2020)

WY 2020 started with a normal onset of wet season rains only to be derailed into a drier than normal condition due to a record-low rainfall in September (Figure 6), largely as a result of several large tropical systems that disrupted the summer pattern. May 2019 water depths were slightly higher than average throughout the Water Conservation Areas, Big Cypress, and most of Everglades National Park (Figure 8, upper maps). Similar to the previous water year, the WY 2020 dry season started earlier than normal as a result (Figure 6). October 2019 water depths were lower than normal throughout the Water Conservation Areas, Big Cypress, and western Everglades National Park (Figure 8, lower maps). Unlike WY 2019, a series of winter storms failed to materialize. Cold fronts proved too infrequent and lacked sufficient moisture to slow the steady decline of the water table. The virtual lack of any rainfall for the entirety of March 2020 (Figure 6) sealed the region's descent into a deep and prolonged drought. Wildfires erupted in the Big Cypress and Everglades in April and May and proved hard to contain due to the loss of surface and shallow ground water from the region's normally wet soils. The wildfires threatened and, in some cases, significantly impacted, large areas of the ecosystem as well as threatened and endangered species found exclusively in both deep slough and upland habitats.

The Everglades and Big Cypress Swamp are flood and fire-adapted ecosystems in which every square inch of flora and fauna depend on a regular return interval and dosage of both flood and fire. In WY 2020, a few months proved pivotal in tilting the region in favor of drought and the wildfires that ensued.

HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL INDICATORS: WATER YEARS 2018-2020

Of interest, both WYs 2019 and 2020, as judged by their annual rainfall of 52 and 48 inches, would appear at first glance to have fallen squarely within the normal 45 to 58 inches of rainfall window. Yet, a closer look reveals a two-year period that was plagued by a continual threat and eventual demise into an ecologically damaging and financially costly drought cycle. The lower than normal water levels in Lake Okeechobee since September 2019 (Figure 9), demonstrate these much drier conditions, which limited water deliveries to the downstream Everglades.

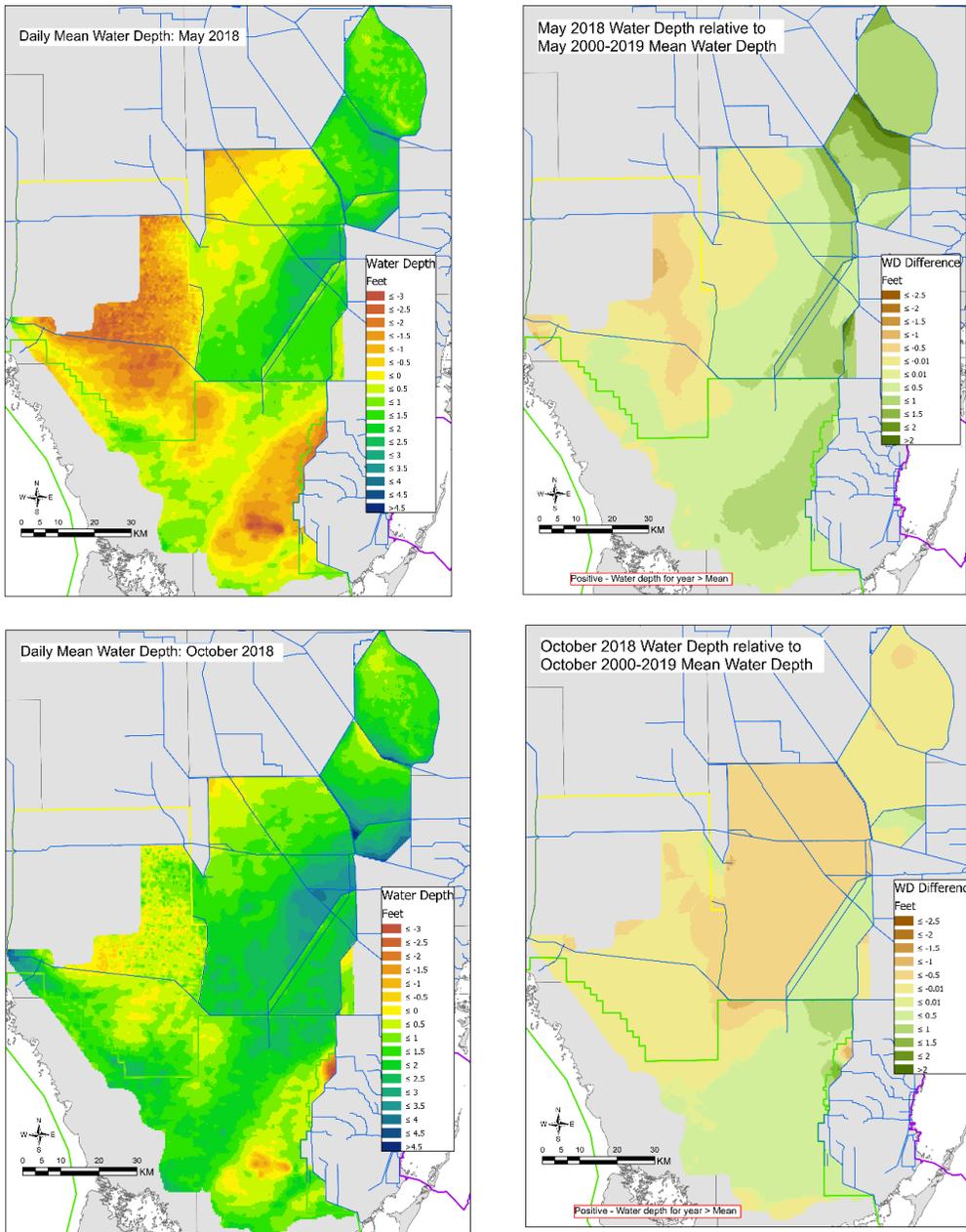


Figure 7. Water depth at the beginning of the 2019 water year (end of dry season) (top left) and wet season (bottom left) and difference from the average water depth at the same time from 2000-2019 (right panels).

HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL INDICATORS: WATER YEARS 2018-2020

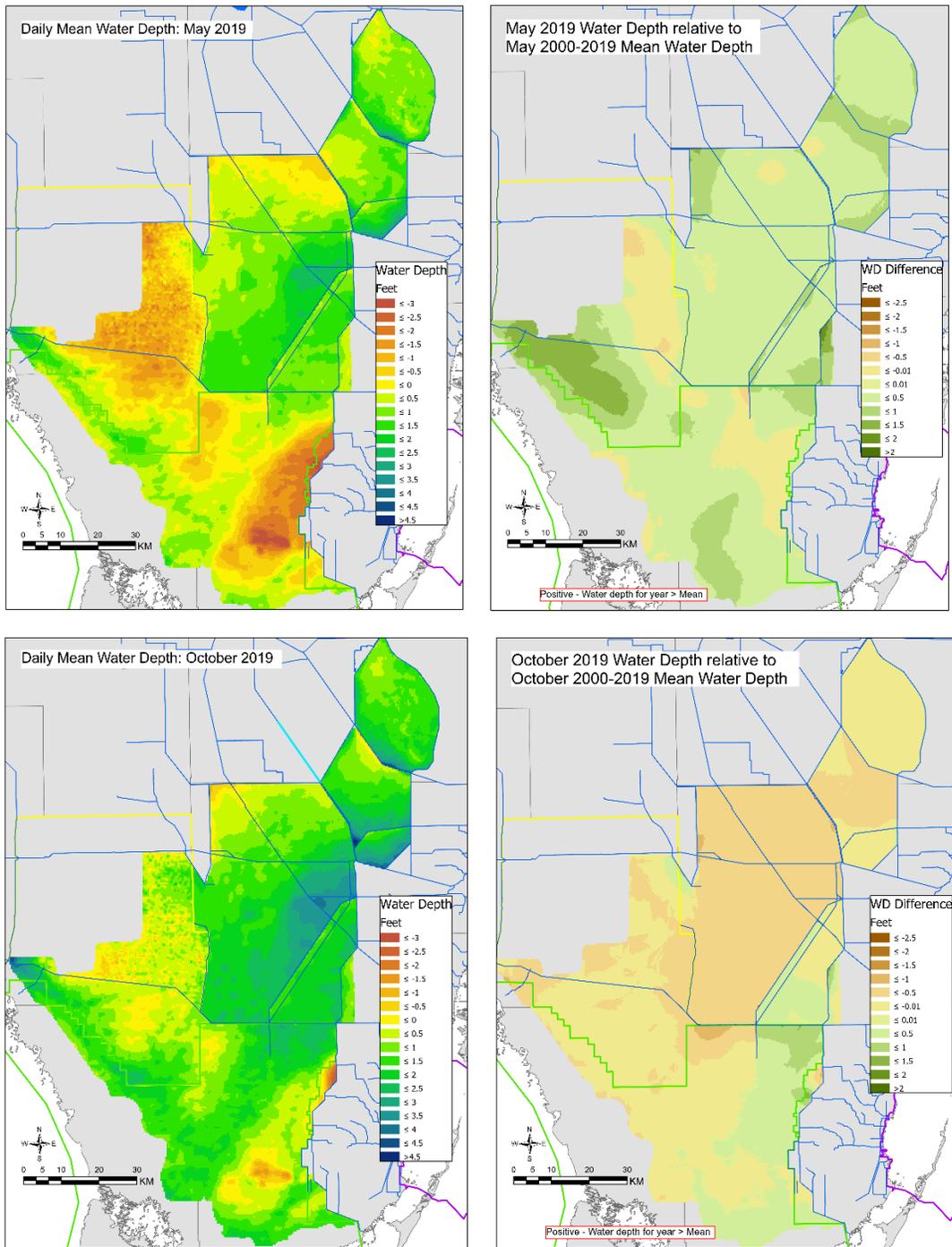


Figure 8. Water depth at the beginning of the 2020 water year (end of dry season) (top left) and wet season (bottom left) and difference from the average water depth at the same time from 2000-2019 (right panels).

HYDROLOGIC CONTEXT FOR THE SYSTEM-WIDE ECOLOGICAL INDICATORS: WATER YEARS 2018-2020

Lake Okeechobee Stage and South Florida Rainfall for Water Years 2019 and 2020

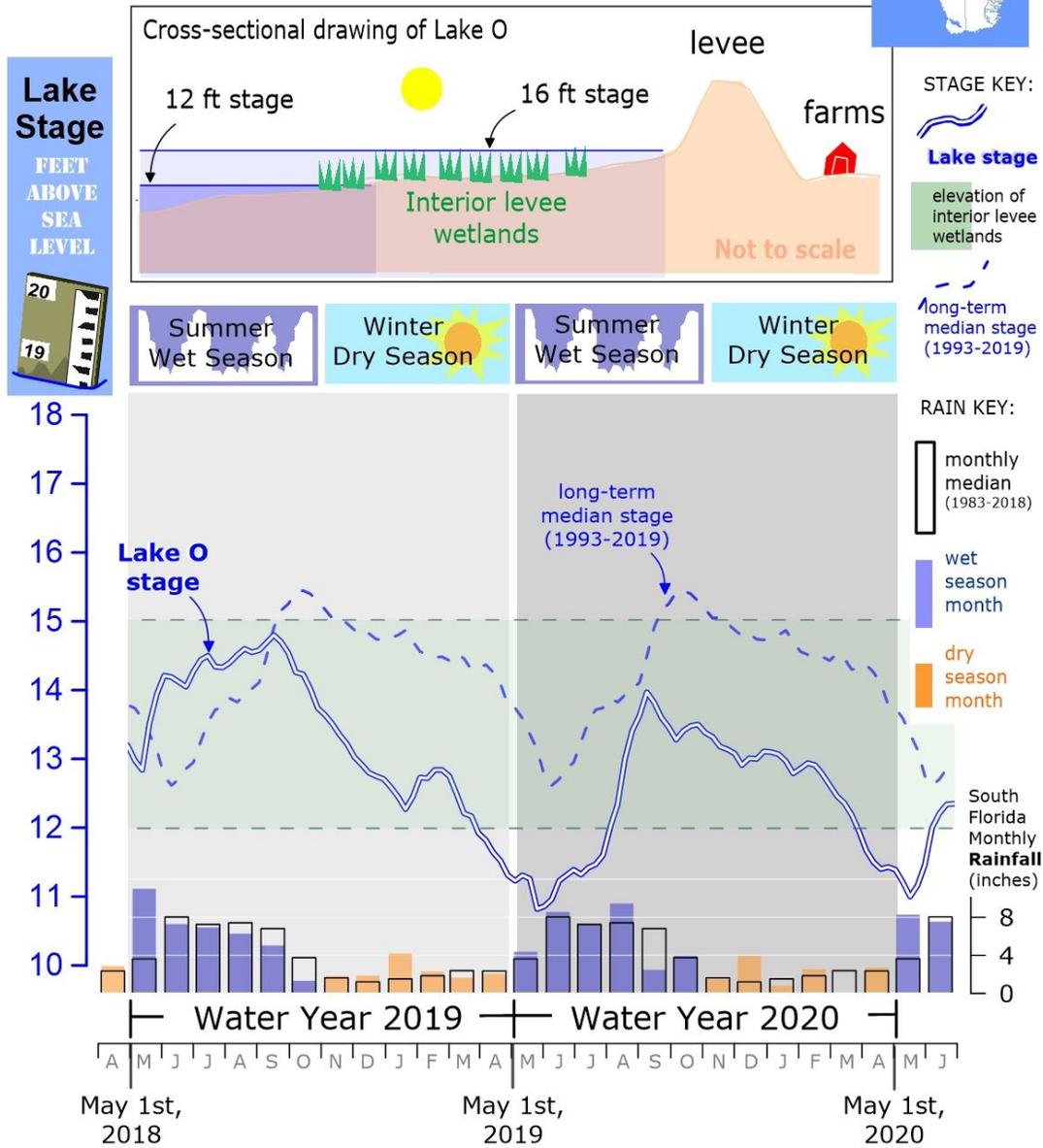


Figure 9. Lake Okeechobee stage and summary of monthly rainfall in the SFWMD in water years 2019 and 2020. Daily rainfall data provided by the SFWMD. District meteorologists compute a daily rainfall value for the fourteen major basins and district wide from rain gauge measurements. See GoHydrology.com for more information.

STOPLIGHT FORMAT

Stoplight Format

Our integrated summary uses colored traffic light symbols that have a message that is instantly recognizable, easy to comprehend, and is universally understood. We used this stoplight restoration report card communication system as a common format for all eleven indicators to provide a uniform and harmonious method of rolling-up the science into an uncomplicated synthesis. This report card effectively evaluates and presents indicator data to managers, policy makers, and the public in a format that is easily understood, provides information-rich visual elements, and is uniform to help standardize assessments among the indicators in order to provide more of an apples-to-apples comparison that managers and policy makers seem to prefer (Schiller et al. 2001, Dennison et al. 2007).

Research and monitoring data are used to develop a set of metrics for each indicator that can be used as performance measures (for example, the number of alligators per kilometer) for the indicator and to develop targets (for example, 1.7 alligators per kilometer) that can be used to link indicator performance to restoration goals. These metrics and targets are different for each indicator. The stoplight colors are determined for each indicator using three steps.

First, the ecological status of the indicator is determined by analysis of quantifiable data collected for each performance measure for each indicator (for example, the data might show that on average there are 0.75 alligators per kilometer). The status of each performance measure is then compared to the restoration targets for the indicators (for example, our target for restoration might be 1.7 alligators per kilometer). The level of performance is then compared to the thresholds for success or failure in meeting the targets and a stoplight color is assigned (for example, 0.75 alligators per kilometer indicates a low number of alligators compared to the target of 1.7 per kilometer and might result in a red stoplight being assigned for this performance measure). These numbers are used for example purposes only.

All of the stoplights were developed directly from the scientific data and the colors of the stoplights—red, yellow, or green—were determined using clear criteria from the results of the data (see 2009 special issue of *Ecological Indicators* Vol. 9, Supplement 6). Because the report is purposely short and succinct, it was not possible to provide information on the approaches used for each indicator in determining thresholds for the individual colors. However, the assessments clearly show how the scientific findings relate directly to the color of the stoplights, providing a transparency from empirical field data to summary data and graphics and then to the stoplight color.

This 2020 report includes a stoplight/key summary status report for each indicator. For more detailed information on these indicators please refer to references listed in each indicator section (if applicable), the Special Issue of *Ecological Indicators: Indicators for Everglades Restoration* (2009), the System-wide *Ecological Indicators for Everglades Restoration 2018 Report*, the 2020 *South Florida Environmental Report*, and the RECOVER 2019 *System Status Report (SSR)* that addresses the overall status of the ecosystem relative to system-level hypotheses, performance measures, and restoration goals.

STOPLIGHT FORMAT

The RECOVER 2019 SSR and 2019 Everglades Health Report Card document the measurement of ecological indicators and performance measures and their application to assess conditions in the Everglades' ecosystems for the years 2012–2017. The SSR also provides the scientific basis/foundation for the Comprehensive Everglades Restoration Plan (CERP) 2020 Report to Congress, required by the Water Resources Development Act of 2000. Produced every five years, the intent of the CERP Report to Congress is to inform the highest levels of the U.S. government on the progress made toward restoration.

Because of broad inter- governmental coordination, the SSR and Everglades Health Report Card incorporate elements of this stoplight indicator update and provides some of the detailed underlying data, theory, and analyses used in this report. The 2019 SSR and Everglades Health Report Card are available at [RECOVER 2019 System Status Report](#) that allows managers, stakeholders, and scientists with varying interests and degrees of technical expertise to easily find the information they need. This combination of indicator reports provides managers with information they need to adjust restoration activities at both large and small scales.

Indicators Overview

Here we provide a short summary of why these organisms are important as ecological indicators for system-wide assessment of restoration, and what the stoplights represent [see Ecological Indicators Special Issue (Vol. 9, Supplement 6 November 2009) for more details].

Invasive Exotic Plants

- ◆ Exotic plants are an indicator of the status of the spread of invasive exotic plants and an indicator of progress in their control and management.
- ◆ Exotic plant distribution is used as an assessment of the integrity of the natural system and native vegetation.
- ◆ Exotic plants can cause ecological changes; therefore, prevention, control, and management are key to restoration of the ecosystem.

Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation (SAV)

- ◆ The lake's SAV community provides habitat for fish and wildlife, offers stability for sediments, and improves water quality.
- ◆ A healthy SAV community directly corresponds to healthy lake conditions.
- ◆ The SAV community is directly influenced by hydroperiod, nutrients, and water quality.
- ◆ Stoplight colors for the Lake Okeechobee nearshore SAV indicators consist of a revised performance measure with total area of summer SAV coverage (target of >50,000 acres) and the interim goal during restoration activities (35,000 acres). These data are derived from the annual summer nearshore SAV mapping project.

Eastern Oysters

- ◆ Oysters provide essential habitat for many other estuarine species.
- ◆ Oysters improve water quality by filtering particles from the water.
- ◆ Water quality, particularly salinity, is directly correlated to the physical health, density, and distribution of oysters in the estuaries.
- ◆ Hydrological restoration in the estuaries should improve the overall distribution and health of oyster reefs.

Crocodylians (American Alligators & Crocodiles)

- ◆ Crocodylians are top predators in the food web affecting prey populations.
- ◆ Alligators are a keystone species and ecosystem engineers.
- ◆ Crocodylians integrate the effects of hydrology in all their life stages.
- ◆ Growth and survival rates of crocodylians are directly correlated with hydrology.
- ◆ Stoplight colors for both the alligator and crocodile indicators incorporate current values, average values, and trends of performance measures over the last 3 or 5 years. For alligators, the performance measures are relative density (#/km), body condition, and occupancy of alligator holes in ENP measured over the last 5, 3, and 3 years, respectively. (Occupancy of alligator holes is not currently included in the calculation since sampling for that performance measure has not been conducted since 2012.) For crocodiles the performance measures are juvenile growth and survival measured over the last 3 and 5 years, respectively.

INDICATORS OVERVIEW

Fish & Macroinvertebrates

- ◆ Fish and macroinvertebrates are critical as a food for predators such as wading birds and alligators.
- ◆ Fish and macroinvertebrates density and community composition are correlated with hydrology.
- ◆ Fish and macroinvertebrates integrate the effects of hydrology in all their life stages.

- ◆ The positive or negative trends of Fish & Macroinvertebrates relative to hydrological changes permit an assessment of positive or negative trends in restoration.

Periphyton

- ◆ Periphyton is comprised of microbes that provide habitat for animals and energy to the rest of the food web.
- ◆ Periphyton is an abundant and ubiquitous Everglades feature that controls water quality and soil formation.
- ◆ The abundance and composition of periphyton is directly tied to water quality and quantity.
- ◆ The nutrient concentration of periphyton is a direct indication of upstream nutrient supply.
- ◆ Periphyton responds very quickly (days) and predictably to changes in environmental conditions and serves as an “early-warning-indicator.”
- ◆ Stoplight colors for periphyton are based on deviation from expected values for abundance, nutrient (phosphorus) concentration, and abundance of calcareous diatom taxa. For each parameter, yellow and red are indicated for values more than one and two standard deviations from mean expected values, respectively. For each wetland basin, yellow is indicated if greater than 25% of sample sites are yellow or red, and red is indicated if greater than 50% of sites are red. Expected values are calculated from the long-term average values from least disturbed sites in each wetland basin.

Wading Birds (White Ibis & Wood Stork)

- ◆ Large numbers of wading birds were a defining characteristic of the Everglades.
- ◆ Their different foraging strategies indicate that large spatial extent and seasonal hydrology made it possible for the historic Everglades to support vast numbers of wading birds.
- ◆ Timing of wading bird nesting is directly correlated with water levels and timing of the availability of prey.
- ◆ Nesting success of wading birds is directly correlated with water levels and prey density.
- ◆ Restoration goals for White Ibis and Wood Storks include recovering spatial and temporal variability to support large numbers of wading birds, restored timing of nesting, and restored nesting success

Southern Coastal Systems Phytoplankton Blooms

- ◆ The Southern Coastal Systems Phytoplankton Blooms indicator reflects the overall water quality condition within south Florida estuaries and coastal waters from the Ten Thousand Islands to Florida Bay to Biscayne Bay.
- ◆ Improved freshwater flows and healthy SAV are expected to significantly reduce the number, scale, and time-span of algal blooms and provide an important indicator of the overall health of the bays.

INDICATORS OVERVIEW

- ◆ Thresholds for this indicator's stoplight colors were developed from long term chlorophyll a concentrations (CHLA) data (1989-present) collected monthly at a large spatial scale. Chlorophyll a concentrations reflect algal biomass. The median and quartiles of CHLA were calculated to quantify the reference conditions for the ten subregions of the southern estuaries. These reference conditions were then used to establish criteria from which the status of CHLA and thus water quality in each of the subregions can be evaluated on an annual basis. If the annual median CHLA concentration is greater than the reference median, but lower than the 75th percentile, the subregion is marked yellow and if the annual median concentration is greater than the 75th percentile of the reference, the subregion is marked red.

Florida Bay Submersed Aquatic Vegetation (SAV)

- ◆ Florida Bay has one of the largest seagrass beds in the world, covering 90% of the 180,000 hectares of the bay.
- ◆ SAV serves many critical functions within estuarine and coastal ecosystems, such as habitat, food, and water quality.
- ◆ The SAV community is correlated to upstream hydrology and water quality.
- ◆ Florida Bay SAV condition is an important indicator for ecosystem restoration because the bay is the receiving basin the South Florida Ecosystem's hydrological system.

Juvenile Pink Shrimp

- ◆ Pink shrimp are an important and characteristic component of the estuarine fauna of the Everglades.
- ◆ Pink shrimp abundance is correlated to freshwater flow from the Everglades.
- ◆ Growth and survival of juvenile pink shrimp are influenced by salinity and are good indicators of hydrological restoration for the estuaries.
- ◆ Pink shrimp were found to be more closely correlated with salinity and seagrass (SAV) conditions than 29 other estuarine species evaluated.

Wading Birds (Roseate Spoonbill)

- ◆ Roseate Spoonbill responses are directly correlated to hydrology and prey availability.
- ◆ Spoonbills time their nesting to water levels that result in concentrated prey.
- ◆ Availability of Roseate Spoonbill prey is directly correlated with hydrology.
- ◆ Positive or negative trends of the Roseate Spoonbill relative to hydrological changes permit an assessment of positive or negative trends in restoration.

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ABOUT THE INDICATORS

About the Indicators

This is a snapshot of the status of each indicator system-wide for the last five years. Results shown here are consistent with previous assessments done by the National Research Council (2012), reflecting the continued patterns of severely altered hydrology throughout the ecosystem.

Because of funding limitations, five of eleven of the indicators have experienced reductions in sampling. Results in this report reflect those reductions and stoplight colors for previous years have been recalculated using comparable data to the reduced effort to allow for comparisons over time. Although we can still present stoplight colors over time, what is reported may be for different geographic areas than was originally designed to capture system-wide responses.

	WY2016	WY2017	WY2018	WY2019	WY2020
Invasive Exotic Plants	Y	Y	Y	Y	C
Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation	R	R	R	R	R
Eastern Oysters- Modified (Northern Estuaries only)	R	R	R	R	R
Crocodylians (American Alligators & Crocodiles)- Modified (DOI Lands Only)	R	R	R	R	C
Fish & Macroinvertebrates (WCA3 and ENP only)	R	R	R	R	R
Periphyton	Y	Y	Y	Y	Y
Wading Birds (White Ibis & Wood Stork)	R	R	Y	R	C
Southern Coastal Systems Phytoplankton Blooms- Modified (no southwest shelf)	R	Y	Y	Y	Y
Florida Bay Submersed Aquatic Vegetation	Y	Y	Y	Y	Y
Juvenile Pink Shrimp- Modified (no sampling)	B	B	B	B	B
Wading Birds (Roseate Spoonbill)	R	R	R	R	R

ABOUT THE INDICATORS

Stoplight Legend

Red (R) Substantial deviations from restoration targets creating severe negative condition that merits action. *Well below restoration target.*

Yellow (Y) Current situation does not meet restoration targets and may require additional restoration action. *Below restoration target.*

Green (G) Situation is within the range expected for a healthy ecosystem within the natural variability of rainfall. Continuation of management and monitoring effort is essential to maintain and be able to assess “green” status. *Meets restoration target.*

Black (B) No data or an inadequate amount of data were collected due to lack of funding.

Clear (C) Data analysis not complete or data not collected due to extenuating circumstances such as COVID 19 in 2020.

Scientists responsible for each indicator were given an outline and asked to provide information for their indicator for each section that was relevant to them (see below). For the time series of stoplights they were asked to provide information for the last five years. Time series from earlier years can be found in the previous System-wide Ecological Indicators for Everglades Restoration reports at [Everglades Restoration Initiatives](#). Indicator sections received minimal editing as they were added to this document.

- Summary/Key Findings
- Time series of stoplights
- Map of WY 2020 stoplight colors (or WY 2019 if WY 2020 not available)
- Updates on calculation of indicator
- Description of: how have these data been used?
- New insights relevant to future restoration decisions
- Literature cited, reports and publications

INVASIVE EXOTIC PLANTS

Summary/Key Findings

STATUS	PREVIOUSLY REPORTED WATER YEAR 2018	WATER YEAR 2019	CURRENT WATER YEAR 2020
SYSTEM-WIDE	Y	Y	Sampling could not be completed because of COVID-19 restrictions

- The proliferation of invasive exotic plant species can lead to substantial negative impacts to native Everglades ecosystems and directly impede restoration success.
- Given the high diversity of invasive plant species and their unique responses to restoration, the Invasive Exotic Plant Indicator assesses the status of invasive plant species collectively and progress in their control.
- Sustained and closely coordinated control efforts across jurisdictions is expected to result in reductions in invasive plant populations and the impacts they exert on native ecosystems.
- All agencies currently operate invasive plant management programs, and regionwide monitoring programs exist for most priority species. However, landscape-level control is hampered by limited financial resources, remote infestations, and in some cases insufficient control methods.
- Continued improvements in invasive species management through coordinated planning, construction, and operational phases of restoration efforts (see CERP Guidance Memorandum 062.00, 2012) are needed to promote more cost-effective management.
- While large portions of the restoration footprint have been cleared and maintained at low infestation levels, the overall geographic distribution of many invasive plant species has increased and in some areas populations previously under control have resurged, largely due to inadequate resources for management. Key regions where invasive plant populations remain problematic include:
 - Kissimmee River floodplain (Old World climbing fern, Peruvian Primrose willow, numerous invasive grass species)
 - A.R.M. Loxahatchee National Wildlife Refuge (melaleuca, Old World climbing fern)
 - Picayune Strand (Brazilian pepper, melaleuca)
 - Everglades National Park—northeastern region (melaleuca, Brazilian pepper, Australian pine)
 - Big Cypress National Preserve—southern region (melaleuca, Brazilian pepper)

On a system-wide scale the Invasive Exotic Plant indicator was below the restoration target (yellow stoplight) at the end of WY 2019. A stoplight color cannot be calculated for WY 2020 because spring sampling could not be completed due to COVID-19 restrictions.

Region-wide systematic reconnaissance flights to measure the abundance and distribution of priority invasive plant species have been rescheduled for January-February 2021. A stoplight calculation was possible for the A.R.M. Loxahatchee National Wildlife Refuge, Kissimmee River Basin, and Lake Okeechobee using other monitoring data sources.

INVASIVE EXOTIC PLANTS

Table 1. Stoplight table for the Invasive Plant Indicator WY 2016 – WY 2020. Red = Substantial deviations from restoration targets creating severe negative condition that merits action. Well below restoration target. Yellow = Current situation does not meet restoration targets and may require additional restoration action. Below restoration target. Green = Situation is within the range expected for a healthy ecosystem within the natural variability of rainfall. Continuation of management and monitoring effort is essential to maintain and be able to assess “green” status. Meets restoration target. Black = No data or inadequate amount of data were collected due to reductions in funding. Clear = Sampling or analysis incomplete or delayed due to COVID-19 so stoplight not available

Invasive Plant Species	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
System-Wide	Y	Y	Y	Y	C
Kissimmee River Basin	R	R	R	R	R
Lake Okeechobee	Y	Y	Y	Y	Y
Northern Estuaries – East Coast	Y	Y	Y	Y	C
Northern Estuaries – West Coast	Y	Y	Y	Y	C
Greater Everglades	Y	Y	Y	Y	C
A.R.M. Loxahatchee National Wildlife Refuge	R	R	R	R	R
Water Conservation Area 2/B	Y	Y	G	G	C
Water Conservation Area 3A	Y	Y	Y	Y	C
Water Conservation Area 3B	Y	Y	Y	Y	C
Everglades National Park	Y	Y	Y	Y	C
Biscayne Bay Complex	Y	Y	Y	Y	C
Southern Estuaries	B	B	B	B	B
Florida Keys	B	B	B	B	B

INVASIVE EXOTIC PLANTS

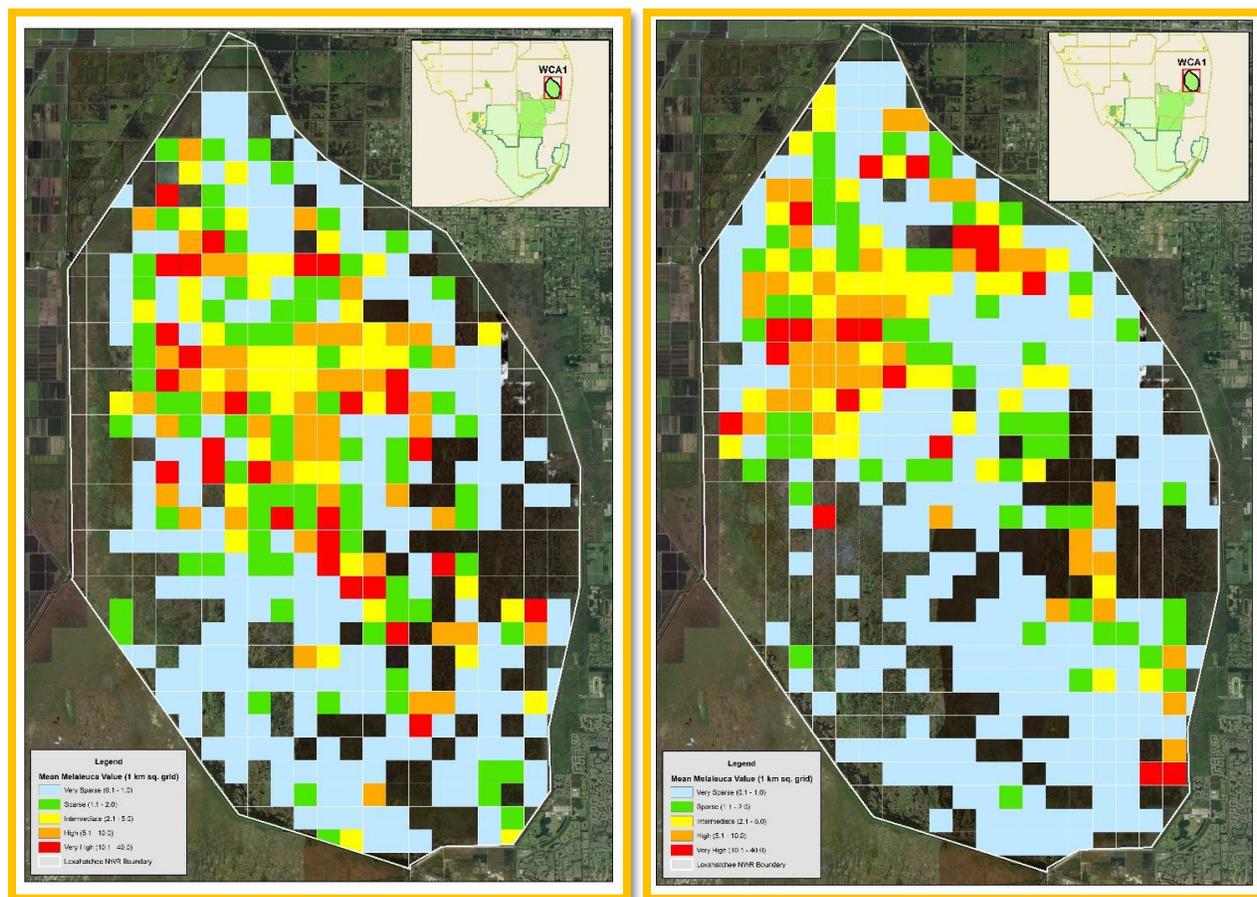


Figure 1. Distribution and abundance of Old World climbing fern (left) and melaleuca (right) at the A.R.M. Loxahatchee National Wildlife Refuge, 2019. Grid cells are 1km. Clear cells indicate species was not detected during sampling event. (see Rodgers et al. 2020).

Table 2. Estimated acres of Old World climbing fern and melaleuca infestation by cover class in the A.R.M Loxahatchee National Wildlife Refuge, 2019. Acreage estimates calculated from aerial species cover estimates using systematic reconnaissance flight methods as described in Rodgers et al. (2020).

Cover class	Infestation Area (hectares)	
	Old World Climbing Fern	Melaleuca
Low (<2%)	10,687	28,340
Medium (2-25%)	5,036	10,689
High (>25%)	522	739
Total	16,246	39,769

INVASIVE EXOTIC PLANTS

Data and Calculations

Updates on calculation of indicator

No changes were made for the calculation of the WY 2019 and WY 2020 scores; however, limited monitoring data results are available for the reporting period. The indicator calculation continues to follow Doren et al (2009), which assesses the status of invasive plant species populations, number of new invasive species present, and availability of monitoring programs and control tools. To assess population status and new species introductions, data is collected from several monitoring protocols as described in Rodgers et al. (2018). Budget constraints and expanded monitoring objectives necessitate reductions in system-wide monitoring from a two-year to five-year interval. Between the systemwide assessments, monitoring has transitioned to address early detection and small-scale mapping to assist land managers with near term treatment activities. The system-wide assessment was planned for 2020, but not completed due to flight restrictions during COVID-19. This component of monitoring for this indicator will be attempted in early 2021. While incomplete monitoring data prevented a system-wide stoplight assessment for 2020, the status of the invasive exotic plant indicator (Doren et al. 2009) remained below the restoration target (yellow stoplight) at the end of WY 2019. Additional monitoring was conducted in several management units within the restoration footprint allowing for some quantification of invasive plant species population status.

How have these data been used?

These data are used to report on the status of invasive species and progress towards their management in the South Florida Environmental Report to meet mandated reporting requirements pursuant to Chapter 2005-36, Laws of Florida, and Section 373.036(7), Florida Statutes (F.S.). Additionally, monitoring data is used to inform land managers of invasive plant expansion or reestablishment, to respond to newly detected invasive plant species, and to assess program-level progress as management efforts continue.

New insights relevant to future restoration decisions

Most of the regions continue to have substantial invasive plant infestations, though many areas have active monitoring and control programs. Despite limited data availability for 2020, land managers report no significant increases in infestation areas in WCA 2A, 2B, 3A, 3B, and Everglades National Park. Field observations from other regions suggest some increases in abundance of certain priority species. For example, several areas within Big Cypress National Preserve are experiencing a substantial expansion of melaleuca resulting from a wildfire. There are now 79 of the 81 Category I Invasive Plant Species (FLEPPC 2019) established in the CERP footprint. These species are known to alter native plant communities by displacing native species, changing community structure or ecological function, or hybridizing with natives. Early detection monitoring resulted in the detection of two invasive species in management units not previously documented.

Repeated follow up herbicide treatments and biological control in WCA 2B have finally yielded maintenance control conditions for all priority invasive plant species as indicated by the green stoplight color in WY 2018 and WY 2019. In addition, a multi-scale monitoring program is in place and funded, and no new invasive plants were recently reported for this area. WCA 2B once had very large melaleuca infestations, and many wondered if the plant could ever be sufficiently controlled there. The melaleuca strategy that relied on integrative pest management, consistent and sufficient management funding, monitoring, regulatory and research support all contributed to WCA 2B finally going green.

INVASIVE EXOTIC PLANTS

Figure 1 shows the 2019 distribution and abundance of two priority invasive plant species—Old World climbing fern and melaleuca—at the A.R.M. Loxahatchee National Wildlife Refuge (Refuge). While many management areas within the Greater Everglades region have reached maintenance level control for these two invasive species, the Refuge remains substantially impacted. Melaleuca and Old World climbing fern is estimated to occur in 39,769 and 16,246 ha, respectively, though most infestations are low to moderate level (Table 2).

Numerous invasive plant species continue to persist in high densities within the Kissimmee River floodplain. Old World climbing fern, creeping water primroses (*Ludwigia* spp.), and several invasive grass species—paragrass (*Urochloa mutica*), limpograss (*Hemarthria altissima*), and West Indian marsh grass (*Hymenachne amplexicaulis*) are common and aggressive invaders in this region. Land managers and restoration scientists are developing management strategies for these species and some control has been achieved. Significant resources will be required to achieve maintenance level control of these species.

Three biological control agents for melaleuca are well-established, and melaleuca reduction is documented (Rayamajhi et al. 2018). Two agents for Old World climbing fern are now established. One of these, the brown lygodium moth, is now widespread and exerting localized pressure on the invasive fern. The recent expansion of the lygodium gall mite from introduction sites is an encouraging development and the pest has shown some localized damage to Old World climbing fern, particularly following fire events. New biological control agents have been released for several other serious invasive plants, and other agents are in development. In 2019, a new agent—Brazilian pepper thrips—was approved for release in the U.S. The CERP Biological Control Implementation Project has substantially increased the number of biocontrol agent releases throughout the CERP footprint.

Monitoring that would identify new invasive species or new distributions for existing species covers the Greater Everglades region (Rodgers et al 2018) and portions of the Kissimmee River, Lake Okeechobee, and Big Cypress regions. These efforts are providing insight into landscape scale distribution and abundance changes for some species, but the ability to identify where and when new species establish is limited. In many cases, invasive plant populations are not being systematically monitored. Overall, the picture remains mixed for invasive plants. Although progress has been made on a number of species, we are still unable to control many species faster than they are invading and spreading. To control species faster than they are invading and spreading, prevention, monitoring, and control programs must be expanded.

INVASIVE EXOTIC PLANTS

Literature Cited, Reports, and Publications

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LAKE OKEECHOBEE NEARSHORE ZONE SUBMERGED AQUATIC VEGETATION

Summary/Key Findings

STATUS	PREVIOUSLY REPORTED WATER YEAR 2018	WATER YEAR 2019	CURRENT WATER YEAR 2020
SYSTEM-WIDE	R	R	R

- Submerged aquatic vegetation (SAV) provides habitat for fish and wildlife, stability for sediments, and improves water quality. A healthy SAV community directly corresponds to healthy Lake Okeechobee conditions. The SAV community is directly influenced by hydroperiod, nutrients, and water quality.
- SAV coverage should expand with completion of Everglades Restoration projects that provide watershed storage and subsequently improve Lake Okeechobee stages (height of the water above mean sea level). Without these projects, rapid inflows from a channelized watershed will continue to drive high lake stages that drown SAV and emergent vegetation during wet conditions. Everglades Restoration will create storage capacity in the watershed, which will prevent dry conditions that drive lake stages down and expose SAV beds, converting open water areas to emergent marshes. It will also allow for favorable water levels that benefit lake ecology and reduced interannual variability should help SAV flourish beyond the 50,000-acre RECOVER annual restoration target.
- While several Everglades Restoration projects, specifically Comprehensive Everglades Restoration Plan (CERP), will affect lake stages to some degree (e.g. C-44, C-43, and Everglades Agricultural Area (EAA) reservoirs), only one upstream project, the Lake Okeechobee Watershed Restoration Project (LOWRP), will directly affect inflows to the lake and improve lake ecology. Through the construction of a reservoir, installation of Aquifer Storage and Recovery wells, and wetland restoration in the watershed, lake stages are expected to remain within desired ranges more frequently, particularly under dry conditions. Over the long-term, such improvements to lake stages should increase coverage of SAV to established targets. The Kissimmee River Restoration project, authorized in 1992 (pre-CERP), may have incidental nutrient load reduction benefits to Lake Okeechobee and provide seasonal changes to inflow patterns, but will not significantly alter inflow volumes to the lake. This project is expected to reduce total phosphorus loads to Lake Okeechobee by 30 metric tons
- To date, no projects have been completed that will impact lake stages. Therefore, watershed storage and downstream storage remain minimal to non-existent, and stages continue to deviate wildly from desired ranges, particularly during wet and dry events.
- SAV declined 81% from WY 2018 to WY 2019, primarily due to effects from Hurricane Irma in September 2017. Direct impacts from the seiche, rapid water level rise, and combined wind and wave energy resulted in a decline of 15,312 acres immediately after Irma. Sub-optimal conditions (high water levels and low light due to suspended sediment in the water column) persisted into WY 2019 and an additional 6,422 acres of SAV was lost. There was a significant recovery in WY 2020, with a total coverage of 26,000 acres (74% of the interim RECOVER goal), aided by lake levels being within or below the ecological envelope for nearly a full year prior. This phenomenon also occurred when low water levels at the end of WY 2017 promoted SAV recovery in WY 2018, improving light penetration and encouraging reestablishment of SAV. While stages were below the ecological envelope for considerable periods of WY 2020,

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERGED AQUATIC VEGETATION

such low water levels are beneficial in recovering habitats affected by high-water or storms like occurred from Hurricane Irma. While not recommended to occur very often or for long durations, such low water levels are key to recovering SAV communities.

The SAV indicator was well below the restoration target (red stoplight) at the end of WY 2018 and remained well below the restoration target at the end of WY 2020 (Table 1). The interim goal has not been met since WY 2013, and SAV coverage has been less than 30,000 acres in four of the past five water years (Figure 1).

Table 1. Stoplight table for Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation for Water Years 2016-2020. Red = less than intermediate goal of 35,000 acres and well below restoration target. Yellow = coverage between 35,000 and 49,999 acres and above intermediate goal but below restoration target. Green = coverage \geq 50,000 acres and meets or exceeds the restoration target.

	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
\geq 50,000 SAV acres restoration target	R	R	R	R	R
35,000 SAV acres intermediate goal	R	R	R	R	R

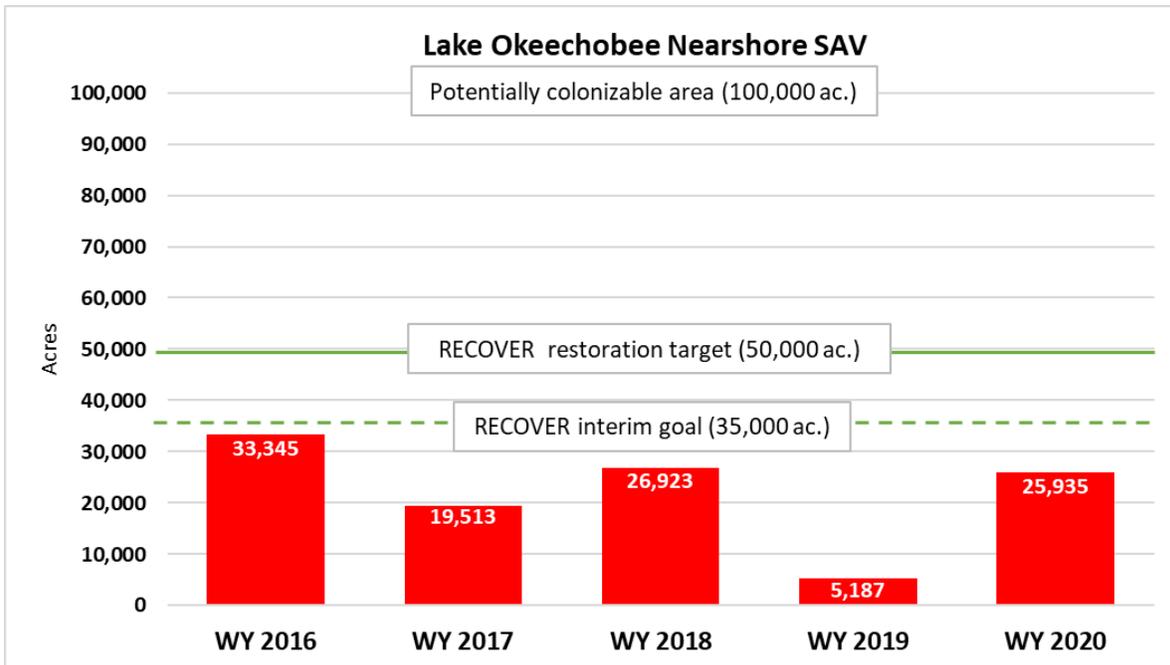


Figure 1. Annual nearshore SAV mapping results for WY 2016 – WY 2020. SAV is sampled during peak growing season (July/August) on a yearly basis.

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERGED AQUATIC VEGETATION

Data and Calculations

Updates on calculation of indicator

No updates since 2016. In 2016 the Lake Okeechobee Nearshore Zone Submerged Aquatic Vegetation Indicator was revised and approved by RECOVER as a performance measure. The new calculation has only one parameter, annual summer (July/August) peak coverage of SAV, while the previous version also included percent of vascular species. The performance measure includes an interim goal of at least 35,000 acres annual areal coverage of SAV. Anything less than 35,000 acres receives a red stoplight. Values between 35,000 and 49,999 receive a yellow stoplight and values $\geq 50,000$ meet the target and receive a green stoplight.

How these data are being used?

Lake Okeechobee SAV is reported in the South Florida Environmental Report and the RECOVER Systems Status Report. The data are being used to help assess habitat conditions for nearshore fish and wildlife, to demonstrate changes in water quality, and to inform short-term water management operations.

New insights relevant to future restoration decisions

Lake level and turbidity act as external forcing functions to drive changes from an SAV / clear water state to a phytoplankton / turbid water state. Thus, the nearshore zone switches between an SAV / clear water state when water levels and turbidity are low to a phytoplankton / turbid water state when there are periods of prolonged high water levels with accompanying sediment resuspension (Havens et al. 2001, 2004, James and Havens 2005).

Even under the 2008 Lake Okeechobee Regulation Schedule (LORS), the lake stage has exceeded the preferred ecological stage envelope (varies seasonally between 11.5 to 15.5 ft above sea level) every water year since WY 2013, except for WY 2020. While the spring of WY 2017 and most of the WY 2018 summer had lake stage below or at the lower end of the ecological stage envelope and SAV increased, Hurricane Irma passed over the lake and its watershed in the fall of WY 2018, pushing lake stage to a max of 17.2 ft; the highest stage since October 2004. Lake stage remained above 16 ft for nearly 2.5 months and stayed above the preferred ecological envelope for nearly 3.5 months, reducing SAV coverage. At the end of WY 2019 and during the growing season of WY 2020, however, lake stages went below the ecological stage envelope and SAV rebounded.

On the basis of annual SAV coverage data collected since WY 2002, maintaining lake stage within the ecologically beneficial stage envelope, both in terms of water depth and temporal ascension and recession rates, provides the best conditions to maximize nearshore SAV coverage. When lake stages have been significantly above or below the envelope, SAV coverage has declined (at least temporarily, in the case of lower water). Restoration activities that provide a significant increase in water storage in the Lake Okeechobee watershed, thereby allowing the lake to more closely follow the timing and depths of an ecologically beneficial stage envelope, should enhance SAV coverage and density in the nearshore region. However, even with better control of lake stage, periodic events such as tropical storms and droughts will continue to influence nearshore

LAKE OKEECHOBEE NEARSHORE ZONE SUBMERGED AQUATIC VEGETATION

SAV coverage. The damage caused by Hurricane Irma significantly decreased coverage, to the second lowest levels since multiple hurricanes impacted the lake in WY 2005-2006; taking several years for the SAV to recover (and aided by significant droughts and low lake stages afterwards). SAV coverage was already low prior to Hurricane Irma after a string of years with relatively high lake stages but subsequent stages at and below the bottom of the ecological stage envelope have been essential in recovering the SAV community.

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EASTERN OYSTERS INDICATOR (NORTHERN ESTUARIES ONLY)

Summary/Key Findings

STATUS	PREVIOUSLY REPORTED (WATER YEAR 2018)	(WATER YEAR 2019)	CURRENT (WATER YEAR 2020)
SYSTEM-WIDE	R	R	R

- Eastern oysters are a natural component of estuaries in south Florida that provide water quality benefits, habitat and food for many species, shoreline stabilization, and important commercial, recreational and economic resources for coastal communities.
- Eastern oysters are frequently used as indicators of water quality because they are a dominant species in the estuarine community and their sedentary nature allows for development of cause-and-effect relationships between environmental conditions and oyster population health and abundance.
- Restoration of more natural freshwater flows to the estuaries will reduce occurrences with abrupt changes in estuarine salinity and temperature and will stabilize oyster population health and abundance. Additionally, successfully restored freshwater flows will allow for reestablishment of oysters at estuarine locations that are currently uninhabitable.
- Eastern oysters will benefit most from the following Everglades Restoration projects: the Indian River Lagoon-South project, the Caloosahatchee C-43 Basin Storage Reservoir, the Central Everglades Planning Project (CEPP) including the EAA Reservoir and Stormwater Treatment Area (STA), and the Lake Okeechobee System Operating Manual update. These projects will improve conditions on both coasts of Florida by providing water storage, reducing detrimental freshwater flows, and maintaining the right amount of essential freshwater flow.
- Eastern oyster status was well below the restoration target for WY 2019 and WY 2020 in the Northern Estuaries (Caloosahatchee River Estuary, St. Lucie Estuary, Loxahatchee River Estuary and Lake Worth Lagoon).
- In WY 2019, oyster populations in the St. Lucie and Caloosahatchee River estuaries began recovering following widespread mortalities that occurred as a result of poor water quality associated with Hurricane Irma in 2017.
- In WY 2020, oyster densities and juvenile recruitment rates continued to improve, but disease rates increased substantially in several estuaries.

On a system-wide scale, the Eastern oyster indicator remains well below the restoration target because the majority of projects (see list of critical Everglades Restoration projects in the fourth bullet point above) that will benefit Eastern oysters have not yet been implemented.

Spotlight scores for the Northern Estuaries and each individual estuary for WY 2016 – WY 2020 are provided in Table 1. Locations of monitored Northern Estuaries and sampling stations within each estuary are shown in Figure 1.

EASTERN OYSTERS INDICATOR (NORTHERN ESTUARIES ONLY)

Table 1. Stoplight Table for Eastern Oysters Indicator (Northern Estuaries Only) for Water Years 2016 –2020. Red = biological parameter scores substantially lower than restoration targets. Yellow = biological parameter scores are below restoration targets. Green = biological parameter scores are within the expected range for Eastern oysters in the Northern Estuaries.

Eastern Oyster	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
Northern Estuaries	R	R	R	R	R
St. Lucie Estuary	R	R	R	R	Y
Loxahatchee River Estuary	R	R	R	G	Y
Lake Worth Lagoon	R	R	R	Y	R
Caloosahatchee River Estuary	R	Y	R	Y	R

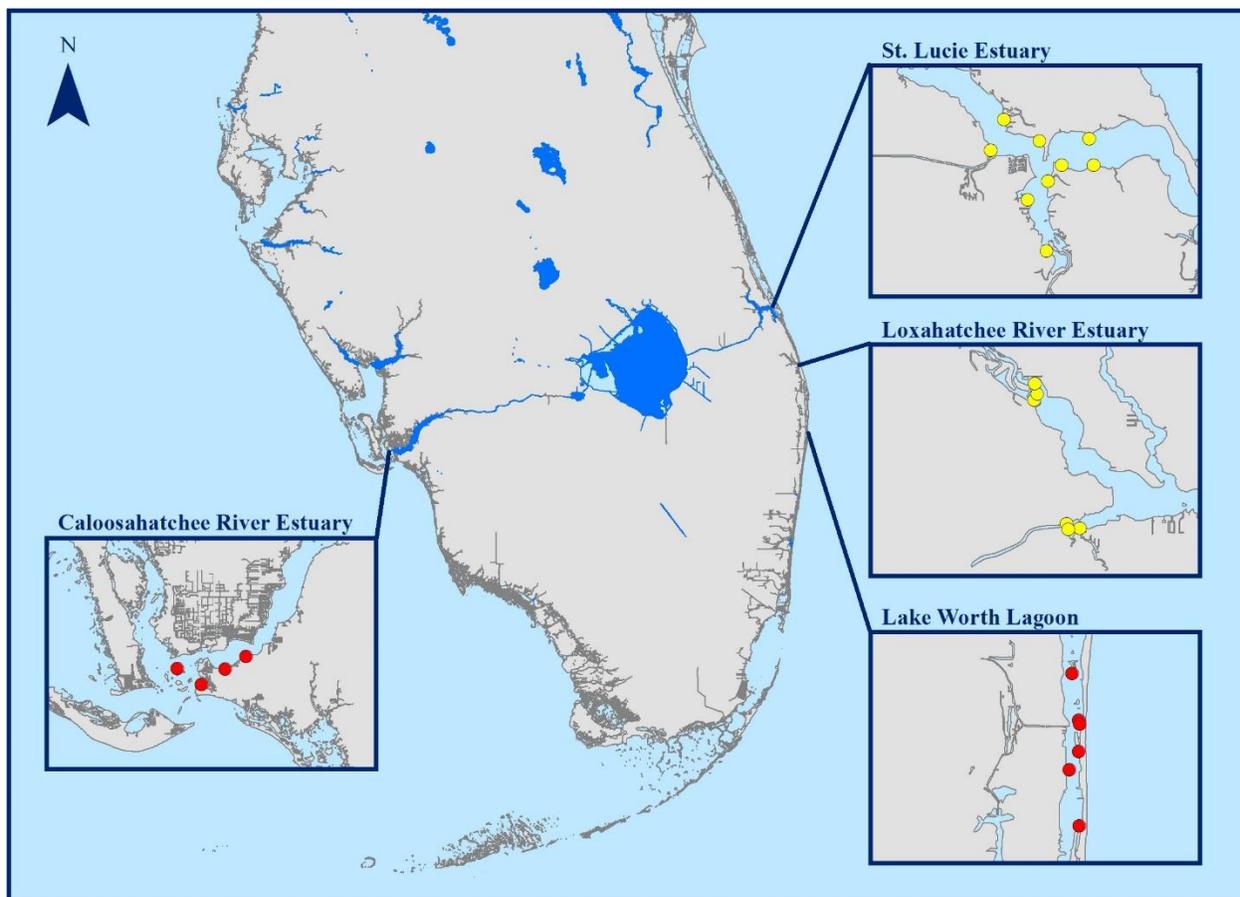


Figure 1. Stoplight colors for Eastern oyster indicator by estuary for WY 2020. Circles represent sampled stations in each estuary. Red circles = biological parameter scores substantially lower than restoration targets. Yellow circles = biological parameter scores are below restoration targets. Green circles = biological parameter scores are within the expected range for Eastern oysters in the Northern Estuaries.

Data and Calculations

Updates on calculation of the indicator

For the St. Lucie Estuary, Loxahatchee River Estuary, Lake Worth Lagoon and Caloosahatchee Estuary, oyster density, larval settlement rates, and prevalence of infections by the parasitic protozoan *Perkinsus marinus* (dermo) were used to calculate scores for each estuary.

How these data are being used?

Oysters continue to serve as one of the principal performance metrics for the Northern Estuaries region of CERP. Oysters are a key component of baseline monitoring prior to construction projects and will be increasingly valuable in assessing how implemented projects affect conditions in the Northern Estuaries.

New Insights relevant to future restoration decisions

Estuary Specific

St. Lucie Estuary

Oyster densities were stable in the SLE, and even increased in the middle estuary, in WY 2017 despite a prolonged period of above optimal salinities during the last half of the WY. Salinities were generally within the optimal range early in WY 2018 but decreased abruptly in September following the extremely powerful and intense Hurricane Irma, which caused a large-scale oyster die-off in the SLE. Although it is evident that the magnitude of freshwater inputs into the SLE following Hurricane Irma were large enough to decimate the oyster population, it is also worth noting that the timing and duration of the freshwater event likely exacerbated the effects and prolonged the recovery period by suppressing reproduction and larval recruitment. No larval recruits were detected in the SLE from September through December 2017, so the next opportunity for recovery was pushed to spring 2018 when the new spawning season began. Salinities in the SLE were within or above optimal in the early months of 2018 and, as anticipated, new spat recruits were detected at most stations by May. Unfortunately, salinities plummeted again in June following heavy rainfall in late May and all newly settled oyster recruits were killed. Salinities remained sub-optimal through early October further delaying oyster recovery in the SLE until late 2018. Live oysters were present at several stations during the September 2018 survey and again at all sampled SLE stations in March 2019. Oyster abundance continued increasing through summer 2019 and remained stable in spring 2020.

Peak reproductive development and spawning activity typically occurs between April and September and is usually greater in the months during or after a period with moderate or higher salinities. Peak larval recruitment rates generally occurred in May of each year; however, there was a smaller magnitude fall peak in WY 2016 and a large magnitude fall peak at the middle estuary stations in WY 2020. Little to no recruitment was detected during periods when salinities were below the optimal range (e.g., WY 2018). Analysis of reproductive development in adult oysters showed that during wet periods, most oysters still completed gametogenesis and spawned. This suggests that the newly spawned larvae either did not survive in the low salinity environment or were physically flushed downstream and out of the estuary.

Disease prevalence from the parasitic protozoan *Perkinsus marinus* (dermo) was low, ranging from 9% to 39% of sampled oysters showing infections. More oysters were infected with the parasite during periods with moderate to high salinities such as those that occurred in WY 2016. Low infection rates generally occur following extended periods with reduced salinities (WY 2018)

EASTERN OYSTERS INDICATOR (NORTHERN ESTUARIES ONLY)

but are also low in recovering populations that are dominated by younger, newly settled oysters that have not been yet been infected by the parasite (WY 2019 and WY 2020). No live oysters were present in the SLE for disease analyses from September 2017 – April 2018 due to die-offs associated with low salinities following Hurricane Irma.

Oyster populations in the SLE continue to be negatively affected by the highly variable freshwater inflows that are a result of the altered local hydrology. Extended periods of high salinities result in gradual increases in disease infection rates that lead to compromised oyster health and survivorship. Periods of extremely low salinities, as occurred in WY 2018, result in acute damage to oyster populations. The rapid transitions between high and low salinity regimes compound the effects of the salinity extremes by reducing the opportunity for acclimatization to new conditions. The timing and duration of extreme low salinity events also greatly affect the severity of the damage to oyster populations. In WY 2018, salinities remained below optimal levels from September through December therefore delaying potential recovery until the initiation of the spawning season in spring 2018.

Loxahatchee River Estuary

The density of live oysters was higher in the Northwest Fork than in the Southwest Fork of the LRE during WY 2016 – WY 2020. No substantial low salinity events occurred in the LRE, but there were more suboptimal salinity days in the Northwest Fork. Those lower salinities likely reduced predation and disease pressures on resident Northwest Fork oysters thus allowing them to survive and thrive, ultimately resulting in the greater densities mentioned above. Live oyster densities in the Northwest Fork were as expected and within restoration targets from WY 2016 through WY 2020. Despite the predominance of above optimal salinities in the Southwest Fork, densities of live oysters remained relatively stable from WY 2016 to WY 2020.

The timing of reproductive development and larval recruitment in the LRE is similar among oysters in the two forks. Reproductive development and spawning activity generally occurred between May and October. Peak spring larval recruitment rates typically occurred in May of each year while peak fall rates occurred most commonly in October; however, there were moderate peaks in August of WY 2016 and WY 2018. One exception worth noting is the absence of a fall peak in September or October during WY 2018. This period coincided with the occurrence of suboptimal salinities following Hurricane Irma. A likely explanation is that the newly spawned larvae either did not survive in the low salinity environment or were physically flushed downstream and out of the estuary. Recruitment rates were generally higher in the NW Fork than the SW Fork, except in WY 2019 when rates were similar in both locations.

Disease prevalence from the parasitic protozoan *Perkinsus marinus* (Dermo) was moderate to high, ranging from 54 to 87% in LRE oysters during most years. These are substantially higher infection rates than seen in oysters from the SLE. Exceptions occurred in the NW Fork in WY 2019 and WY 2020 when rates declined to less than 20% during or following months with reduced salinities. In other WYs, mean infection prevalence in the NW Fork exceeded 50%. These high infection rates in both forks indicate that freshwater inflows into the estuary have generally not been of sufficient magnitude or duration to provide prolonged relief from disease pressure.

Oyster populations in the LRE have been negatively impacted by the variable freshwater inflows that are a result of the altered local hydrology. Extended periods of high salinities result in gradual

increases in disease infection rates that lead to compromised oyster health and survivorship. If salinities rapidly decrease to suboptimal levels, as occurred in WY 2018, the opportunity for

EASTERN OYSTERS INDICATOR (NORTHERN ESTUARIES ONLY)

acclimatization to new conditions is reduced or eliminated and the local oysters are more susceptible to predation and disease. High salinities are a persistent problem in the LRE but there is evidence that brief excursions to optimal salinities, or even suboptimal salinities, can substantially reduce disease rates and increase reproductive capacity. However, the timing of these low salinity events determines if there will be a positive or negative outcome. In WY 2018, the low salinity events occurred just prior to and during the spawning season leading to substantially reduced larval recruitment rates.

Lake Worth Lagoon

The density of live oysters was moderate in LWL during WY 2016 – WY 2020. No substantial low salinity events occurred in LWL, but there were more suboptimal salinity days in WY 2018 following Hurricane Irma. Those lower salinities likely reduced predation and disease pressures on resident LWL oysters thus allowing them to better survive and thrive. Despite the predominance of above optimal salinities in LWL, densities of live oysters remained relatively stable from WY 2016 to WY 2020.

Reproductive development and spawning activity generally occurred between May and December. Peak larval recruitment rates typically occurred in September or October of each year; however, there was a moderate peak in May of WY 2016. Recruitment patterns differed substantially in WY 2018, when peak rates were measured in June and July and much lower recruitment rates were detected in the fall. This missing fall recruitment peak was most likely due to the occurrence of suboptimal salinities following Hurricane Irma. The lowest recruitment rates were measured in WY 2019 likely due to the lower salinities that occurred during the summer months.

Disease prevalence from the parasitic protozoan *Perkinsus marinus* (Dermo) was high and ranged from 52 to 77% in LWL oysters. These are substantially higher infection rates than seen in oysters from the SLE. The lowest infection rates (WY mean of 65% and 52%) in oysters from LWL were measured in WY 2018 and WY 2019 during or following months with reduced salinities. These high infection rates indicate that freshwater inflows into the estuary have generally not been of sufficient magnitude or duration to provide relief from disease pressure.

Oyster populations in LWL have been negatively impacted by the variable freshwater inflows that are a result of the altered local hydrology. Extended periods of high salinities result in gradual increases in disease infection rates that lead to compromised oyster health and survivorship. High salinities are a persistent problem in LWL but there is evidence that brief excursions to optimal salinities, or even suboptimal salinities, can substantially reduce disease rates and increase reproductive capacity.

Caloosahatchee River Estuary

The density of live oysters at sampled stations in the CRE is highly variable and greatly influenced by freshwater inflows and the resultant salinity fluctuations along the upstream to downstream gradient. During most density surveys, oyster numbers were greatest at one of the upstream stations while the lowest densities of live oysters were found at the most downstream station. During WY 2017 and WY 2018, when freshwater inflows were high and salinities were near zero, oysters at the upstream stations disappeared or were present only at very low densities.

EASTERN OYSTERS INDICATOR (NORTHERN ESTUARIES ONLY)

Reproductive development and spawning activity generally occurred between April and November in the CRE. Peak larval recruitment rates typically occurred in August or September of each year; however, there was an earlier peak in April at the end of WY 2016. Despite extended periods of suboptimal salinities in WY 2016/2017 and WY 2018, larval recruitment in the CRE continued, oftentimes at moderate to high rates. Recruitment rates in the CRE were as expected and within restoration targets from WY 2016 through WY 2020.

Disease prevalence from the parasitic protozoan *Perkinsus marinus* (Dermo) was moderate to high ranging from 30% to 89% in CRE oysters. These are much higher infection rates than seen in SLE oysters. The lowest infection rates (WY means of approximately 30%) occurred in WY 2018 after Hurricane Irma and in WY 2019 when the population was dominated by younger, newly settled oysters that have not been yet been infected by the parasite. No live oysters were present for disease analyses at the upstream stations in the CRE from September 2017 – April 2018 due to die-offs associated with low salinities following Hurricane Irma.

Oyster populations in the CRE continue to be negatively affected by the highly variable freshwater inflows that are a result of the altered local hydrology. Extended periods of high salinities result in gradual increases in disease infection rates that lead to compromised oyster health and survivorship. Periods of extremely low salinities, as occurred in WY 2016/2017 and WY 2018, result in acute damage to upstream oyster populations. The rapid transitions between high and low salinity regimes compound the effects of the salinity extremes by reducing the opportunity for acclimatization to new conditions. The timing and duration of extreme low salinity events also greatly affect the severity of the damage to oyster populations. Extended periods of above optimal or below optimal salinities are a persistent problem in the CRE but there is evidence that even brief periods of more moderate salinities can greatly enhance oyster density and reproductive output as well as reduce disease infection rates.

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CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

SUMMARY/KEY FINDINGS

STATUS	PREVIOUSLY REPORTED (WATER YEAR 2018)	WATER YEAR 2019	CURRENT (WATER YEAR 2020)
SYSTEM-WIDE (Modified USDOI lands only)	R	R	Could not complete sampling because of COVID-19 restrictions

- In the Everglades, crocodilians (alligators and crocodiles) are important ecosystem engineers creating both high ground (nests) and low areas (alligator holes, trails) habitats that promote species diversity in the ecosystem.
- Health and growth of crocodilian populations and individuals are directly related to wetland hydrology and estuarine salinity.
- We expect positive responses in crocodilian growth, survival, body condition, and relative densities (estimated abundance) in marsh areas where Everglades Restoration projects (such as Modified Water Deliveries and the Tamiami Trail bridge projects) are intended to restore multi-year hydroperiods, more natural fluctuations in water depths, and more natural water deliveries to estuaries.
- With the implementation of one group of Everglades Restoration projects, the Central Everglades Planning Project, we expect to see improvement in body condition and estimated abundance of alligators in areas where densities are currently low because of drier conditions, such as in northern WCA3A and Northeastern Shark River Slough.
- We expect to see more crocodiles in better body condition with higher growth and survival rates in areas where projects that deliver more fresh water to coastal habitats have been implemented such as northeastern Florida Bay.

On a system-wide scale the crocodilian indicator remains well below the restoration target because the majority of projects intended to benefit crocodilians have not yet been implemented.

*A full system-wide status assessment for crocodilians for WY 2018–WY 2020 cannot be provided because some survey routes have not been sampled since funding was suspended in WY 2012. However, surveys have continued on some USDOI lands (LNWR, Crocodile Lake National Wildlife Refuge and ENP).

Funding for surveys in WCA-3A and 3B was restored in WY 2016. Full stoplight assessment for WCA3 can be included after completion of 5 years of data collection. We have provided a summary of yearly estimated abundance and body condition for those routes as well as for a new route in Northeast Shark River Slough (ENP-NESSE, Table 1).

An overall stoplight color cannot be calculated for WY 2020 because spring sampling could not be completed due to COVID-19 restrictions, thus Figure 1 presents overall stoplight colors for WY 2019.

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

Because we have updated how we calculate relative density, which we now refer to as estimated abundance, we have provided the full time series of overall stoplight colors using data from WY 2004 – 2020 and the updated calculations (Table 2, see updates on calculation of the indicator section below). We also have provided graphical representation of the yearly estimated abundance (Figure 2) and body condition (Figure 3) components of the overall indicator for data collected WY 2004–2020. See Mazzotti et al. (2009) for how these components are used to calculate the overall indicator.

Table 1. Average and 95% confidence intervals for two surveys for spring estimated alligator abundance and the lower of the average spring or fall body condition values with confidence intervals () for 15 alligators in WCAs 3A and 3B and ENP-NESSE in WY 2017, WY 2018, WY 2019, and WY 2020. Estimated abundance values are now being calculated using an N-mixture hierarchical model (see update on calculation of indicator section below). Estimated abundance for WY 2020 was not calculated (N/A) due to insufficient spring data because of University of Florida restrictions on fieldwork during the Covid-19 pandemic. *Body condition values for WY 2020 were calculated using only fall data because of spring sampling restrictions. ENP-NESSE only had sufficient spring survey data in WY 2018 because of low water levels causing limited access. Fall WY 2018 was the only season in ENP-NESSE in which at least 15 animals were captured to calculate body condition. Eleven animals were captured in fall WY 2019 and six animals were captured in fall WY 2020 in ENP-NESSE. WCA3A-Tower had 13 captures in fall WY 2020. **These captures were utilized for the calculations presented here.

Route	Estimated abundance Alligators/km				Body condition Fulton's K			
	WY 2017	WY 2018	WY 2019	WY 2020	WY 2017	WY 2018	WY 2019	WY 2020
WCA3A - Tower	1.42 (0.60-4.60)	1.03 (0.20-4.20)	0.99 (0.33-4.33)	N/A	2.15 (2.05-2.24)	2.10 (1.95-2.25)	2.30 (2.13-2.46)	2.23** (2.09-2.36)
WCA3A - Holiday	6.15 (2.60-11.21)	6.05 (2.19-12.56)	4.27 (1.44-9.67)	N/A	2.10 (1.99-2.21)	2.12 (2.03-2.21)	2.03 (1.92-2.13)	2.15* (1.95-2.36)
WCA3A - N41	6.22 (2.09-12.77)	7.21 (2.95-13.73)	5.47 (2.23-10.77)	N/A	1.95 (1.85-2.05)	2.08 (1.90-2.29)	2.22 (2.15-2.29)	2.13* (2.03-2.24)
WCA3B	2.26 (1.12-5.30)	2.14 (1.07-5.12)	1.49 (0.56-4.60)	N/A	2.14 (2.00-2.29)	2.23 (2.10-2.36)	2.07 (1.93-2.22)	2.15* (2.06-2.24)
ENP-NESSE	N/A	0.43 (0.17-2.17)	N/A	N/A	N/A	2.29 (2.14-2.43)	2.14** (1.86-2.42)	2.26** (1.92-2.61)

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

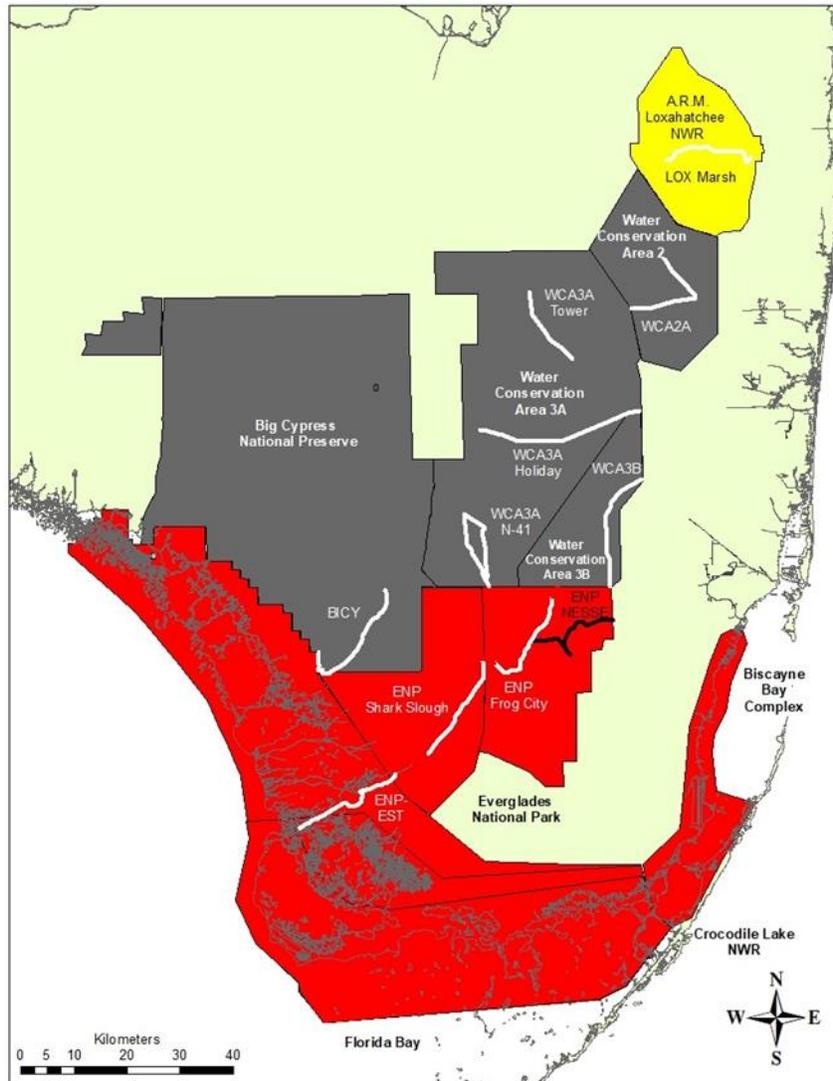


Figure 1. Stoplight colors for crocodilian indicator by management unit for WY 2019. Red = Substantial deviations from restoration targets creating severe negative condition that merits action. Well below restoration target. Yellow = Current situation does not meet restoration targets and may require additional restoration action. Below restoration target. Green = Situation is within the range expected for a healthy ecosystem within the natural variability of rainfall. Continuation of management and monitoring effort is essential to maintain and be able to assess “green” status. Meets restoration target. Black = No data or inadequate amount of data were collected due to reductions in funding. Color for Water Conservation Areas and interior Everglades National Park (ENP) are from American alligator (*Alligator mississippiensis*) scores only. Colors of coastal ENP and Biscayne Bay are from combined scores of American alligators and American crocodiles (*Crocodylus acutus*). Survey routes are highlighted in each area by either a white (routes started in 2004) or black line (new route started in 2017).

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

Table 2. Stoplight table for Crocodilians (American Alligator & Crocodiles) Indicator –WY 2008 – WY 2020.

Red (R) Substantial deviations from restoration targets creating severe negative condition that merits action. *Well below restoration target.*

Yellow (Y) Current situation does not meet restoration targets and may require additional restoration action. *Below restoration target.*

Green (G) Situation is within the range expected for a healthy ecosystem within the natural variability of rainfall. Continuation of management and monitoring effort is essential to maintain and be able to assess “green” status. *Meets restoration target.*

Black (B) No data or an inadequate amount of data were collected due to lack of funding.

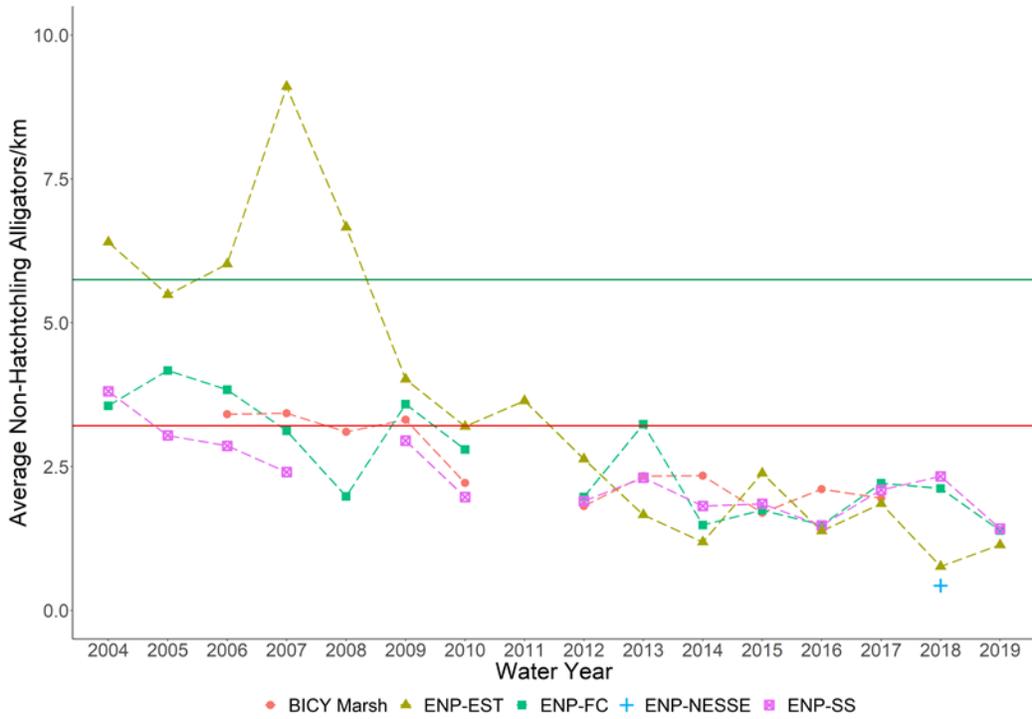
Clear (C) Sampling or analysis incomplete or delayed so stoplight not available.

American Alligators and Crocodile	WY 2008	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
System-wide	R	Y	Y	Y	B	B	B	B	B	B	B	B	C
DOI Lands	R	Y	Y	Y	R	R	R	R	R	R	R	R	C

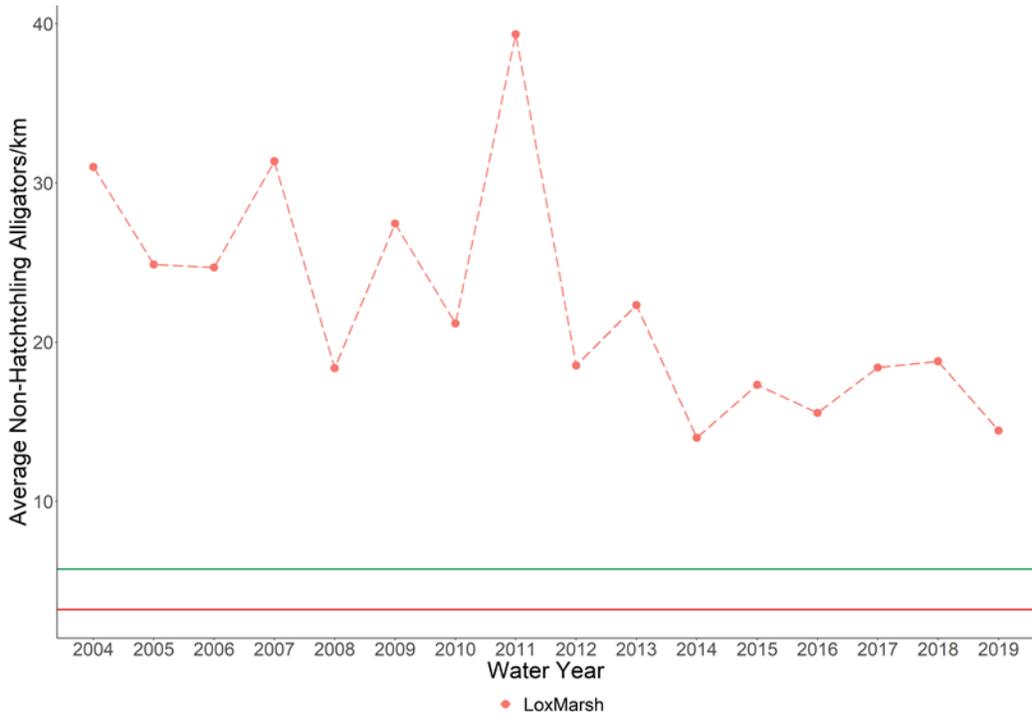
	WY 2008	WY 2009	WY 2010	WY 2011	WY 2012	WY 2013	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
American Alligator													
A.R.M. Loxahatchee National Wildlife Refuge	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	C
Water Conservation Area 2A	R	C	R	R	B	B	B	B	B	B	B	B	B
Water Conservation Area 3A	Y	Y	Y	Y	B	B	B	B	B	B	B	B	B
Water Conservation Area 3B	C	R	R	C	B	B	B	B	B	B	B	B	B
Everglades National Park	Y	Y	Y	Y	R	R	R	R	R	R	Y	R	C
Big Cypress National Preserve	R	R	Y	C	R	R	R	R	Y	R	B	B	B
American Crocodile													
Everglades National Park	R	R	R	R	R	Y	Y	Y	R	R	R	G	Y
Biscayne Bay Complex	R	R	Y	R	R	R	R	R	R	R	R	R	C

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

A)



B)



CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

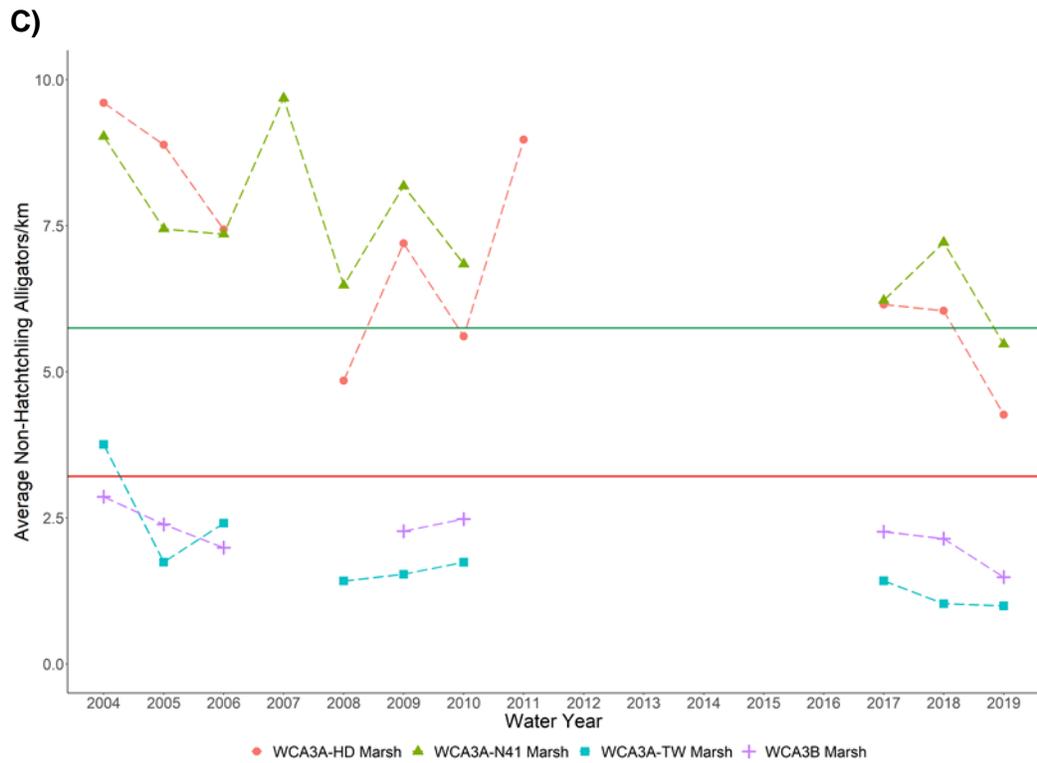
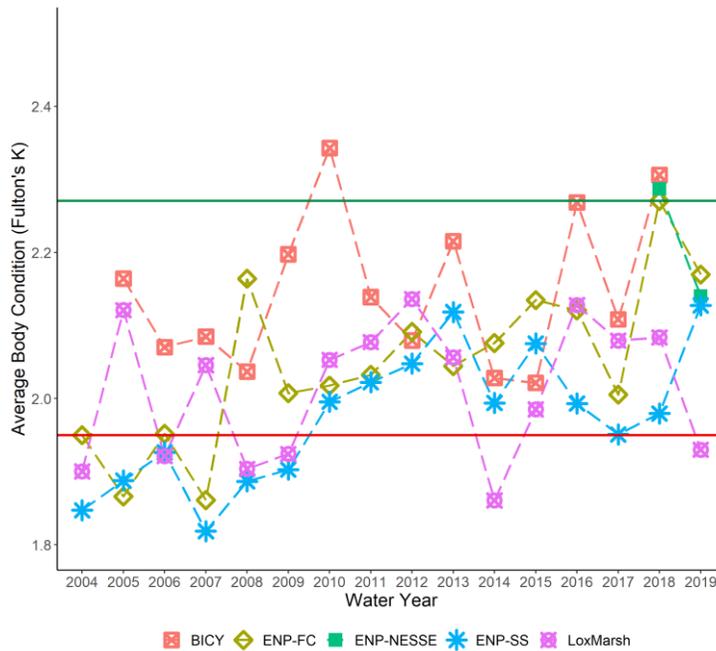


Figure 2. Average non-hatchling alligators/km (estimated abundance) from two spring surveys by water year for WY 2004–WY 2019 in areas where alligators are monitored. Estimated abundance values are now being calculated using an N-mixture hierarchical model (see updates to calculation of indicator section below). Top green line indicates restoration target. Bottom red line indicates conditions well below the restoration target.

A) is DOI lands other than Arthur R. Marshall Loxahatchee National Wildlife Refuge.
 B) is Arthur R. Marshall Loxahatchee National Wildlife Refuge.
 C) Is Water Conservation Area 3. WCA3A and WCA3B were not sampled during WY 2012–2016 due to lack of funding. Spring samples could not be completed in WY 2020 because of restrictions due to COVID-19.

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

A)



B)

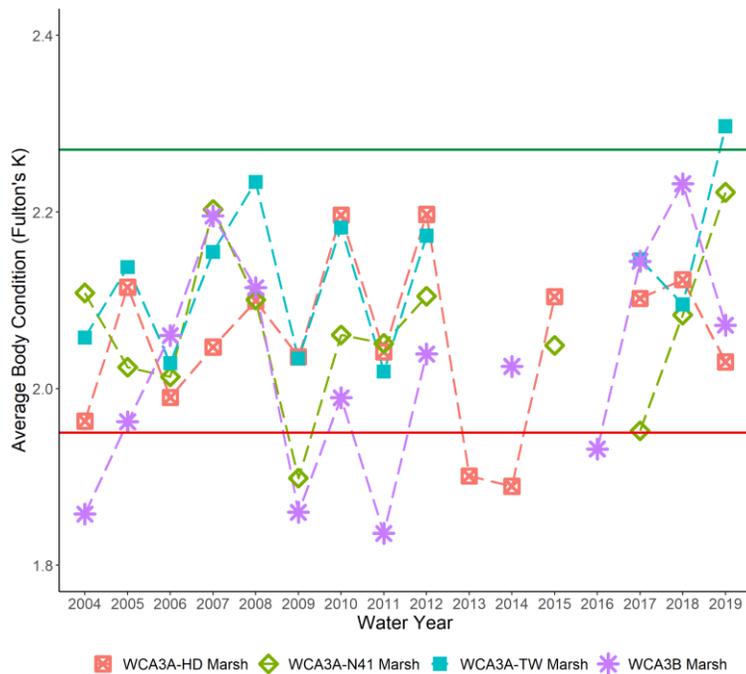


Figure 3. Average alligator body condition (Fulton's K) in areas where alligators are monitored in WY 2004–WY 2020. Sampling occurs in spring and fall. A) is DOI lands. B) is Water Conservation Area 3. Top green line indicates restoration target. Bottom red line indicates conditions well below the restoration target. WY 2020 data are for fall only because spring sampling could not be completed because of COVID-19 restrictions.

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

Data and Calculations

Updates on calculation of indicator

For alligators, several changes have occurred in sampling and hence in how we are able to calculate the indicator. Originally, we had 10 marsh routes. With funding cuts in 2011, we only continued sampling on DOI lands including A.R.M. Loxahatchee National Wildlife Refuge, Everglades National Park, and Big Cypress National Preserve (a total of 5 routes). In 2016, funding was restored to sample in WCA3A&B and we will be able to incorporate those routes into the overall stoplight calculation after 5 years of data collection. Currently, there is only partial funding for routes on DOI lands and sampling in the Big Cypress National Preserve was paused in 2018. Calculation of overall stoplight scores have taken these changes in routes into account.

We have updated how we calculate the relative density portion of the alligator stoplight to take detection probability into account and now refer to it as estimated abundance. We are using the N-mixture model of Royle (2004). This hierarchical model estimates detection probability (p) and abundance (λ) using spatially replicated count data and is appropriate for use for open populations (those where abundance may change over time). We are using both a single season model for looking at individual years and a dynamic model for observing trends across multiple years. The dynamic model estimates abundance across multiple years and assumes that the population is open (Fiske and Chandler 2011, Dail and Madsen 2011). Full details of the modeling are described in Farris et al. In Prep. Table 3 has the stoplight cutoffs for all crocodilian parameters including the new values for Relative Abundance.

Table 3. Stoplight cutoff values for crocodilian parameters used to calculate the overall stoplight color. Relative Abundance will now be estimated using and N-mixture model.

Parameters	Red	Yellow	Green
Alligator Estimated Abundance (alligators/km)	0 - < 3.92	3.92 – < 6.37	≥ 6.37
Alligator Body Condition (Fulton’s K with SVL (cm) and Mass (g))	0 - ≤ 1.95	> 1.95 - ≤ 2.27	> 2.27
Crocodile Six Month Survival (%)	0 - ≤ 0.64	> 0.64 - ≤ 0.85	> 0.85
Crocodile Juvenile Growth (cm/day)	0 - ≤ 0.068	> 0.068 - ≤ 0.15	> 0.15

How these data are being used?

Some of the data presented here are a part of the monitoring program for the Modified Water Deliveries project. Crocodile data continue to inform the Species Status Assessment (SSA) being completed by the US Fish and Wildlife Service (USFWS). The SSA is an analytical approach developed by the USFWS to deliver foundational science for informing Endangered Species Act decisions.

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

New insights relevant to future restoration decisions

Alligators

The establishment of a new survey route for alligators in Northeastern Shark River Slough (NESSE) in fall 2017 now provides us two routes (Frog City and NESSE) that will allow us to assess the effects of the Modified Water Deliveries to ENP and Tamiami Trail bridging project. It also provided us with some insights that we used to refine protocols and combined with observations make some suggestions on additional metrics that we can use to track progress toward restoration.

Because low water depths impeded our access to the ENP-NESSE route during spring 2018, the latter half of fall 2018, spring 2019, and spring 2020 we have revised our protocol to incorporate collection of water depths at more locations when low water depths impair survey route access or cause unsafe airboat operating conditions. Thus, we will have water depth at the locations (taken with a GPS) where we terminate the survey. Our expectation is that as hydrologic conditions continue to improve, we will be able to consistently complete more of the survey route and expend less time to capture 15 alligators. Therefore, we suggest that access to our Northeastern Shark River Slough survey routes, particularly ENP-NESSE, and catch per unit effort for these routes could be used as other indicators to evaluate the success of the Modified Water Deliveries and Everglades restoration in Northeastern Shark River Slough. We can also use these metrics in other areas such as our WCA3A Tower route which continues to dry out sooner and more often than it did when it was originally established.

Incorporating the findings of other Everglades restoration monitoring projects, such as fish and invertebrate monitoring (Kominoski et al. 2019), has allowed us to evaluate the results our alligator monitoring in Northeastern Shark River Slough with greater context. Our recommended hydroperiod target for alligators is >11 months per year with dry-down no longer than 40 days, or about 1.25 months. Hydrologic monitoring associated with fish and invertebrate monitoring in Northeastern Shark River Slough indicated that the hydroperiod was highly variable, indicating that recommended targets are not yet met. The average hydroperiod in the fish and invertebrate monitoring study varied from a minimum of 88 days (~3 months) to a maximum of 225 days (~7.5 months) during 2012, 2015, and 2018. These hydroperiods are below our recommended hydroperiod target for alligators. The hydroperiod is expected to increase and length of dry-downs expected to decrease as the Modified Water Deliveries and Tamiami Trail modification project goals are met and Everglades ecosystem restoration proceeds.

Crocodiles

We have continued to work on our understanding of the relationship between crocodile growth and salinity. From a long-term mark-recapture dataset (329 crocodiles captured 1978–2015) we showed that salinity conditions during the dry season is critical to crocodilian growth and explained 91% of the variation in growth rates. Crocodiles exposed to hypersaline conditions (>40 psu) for a minimum of 30 days during the dry season experienced reduced growth rates compared to crocodiles experiencing intermediate (20–40psu) and low salinity conditions (<20 psu).

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

After the first year of life, crocodiles under high salinity conditions (exposure to >40 psu for more than 30 days) had a 13% decreased growth rate and a 24% decreased growth rate after 5 years of age. After 10 years, crocodiles in hypersaline conditions had a 29% decreased growth rate (Figure 4a). Crocodiles also exhibited differential growth rates based on where they were captured. Crocodiles captured in NE Florida Bay had slower growth rates than those captured in Flamingo and Cape Sable areas (highest growth rates) and West Lake and 7Palm areas (intermediate growth rates, Figure 4b). We hypothesize that growth rates among areas are related to nutrient levels and prey availability, whereas variation in growth rates within an area are related to salinity.

We also have continued to improve our understanding of crocodile survival using a dataset of 9,040 crocodiles captured as hatchlings between 1978–2015. We calculated an overall 25% hatchling survival rate for south Florida that quickly increases to 40% survival after the first year. However, there were significant location effects on survival. Crocodiles captured in NE Florida Bay had the lowest hatchling survival estimates at 34%, compared with a 69% survival rate for hatchling crocodiles captured in Croc Lake NWR, 58% in Flamingo area, and 48% in Biscayne Bay (Briggs-Gonzalez et al. in prep).

Using the same long-term dataset, we calculated an average body condition of 2.17 ± 0.36 SD for 859 non-hatchling crocodiles captured between 1978–2015. Among locations, crocodiles captured from Flamingo and Cape Sable had a condition index much higher (> 2.25) than crocodiles in NE Florida Bay (average 2.03), with a mean body condition of 2.17 for South Florida (Briggs-Gonzalez et al. in prep). Crocodile body condition also decreased with more than 30 days exposed to hypersaline conditions. We can use this information to complete development of a crocodile body condition performance measure similar to what we have developed for alligators.

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

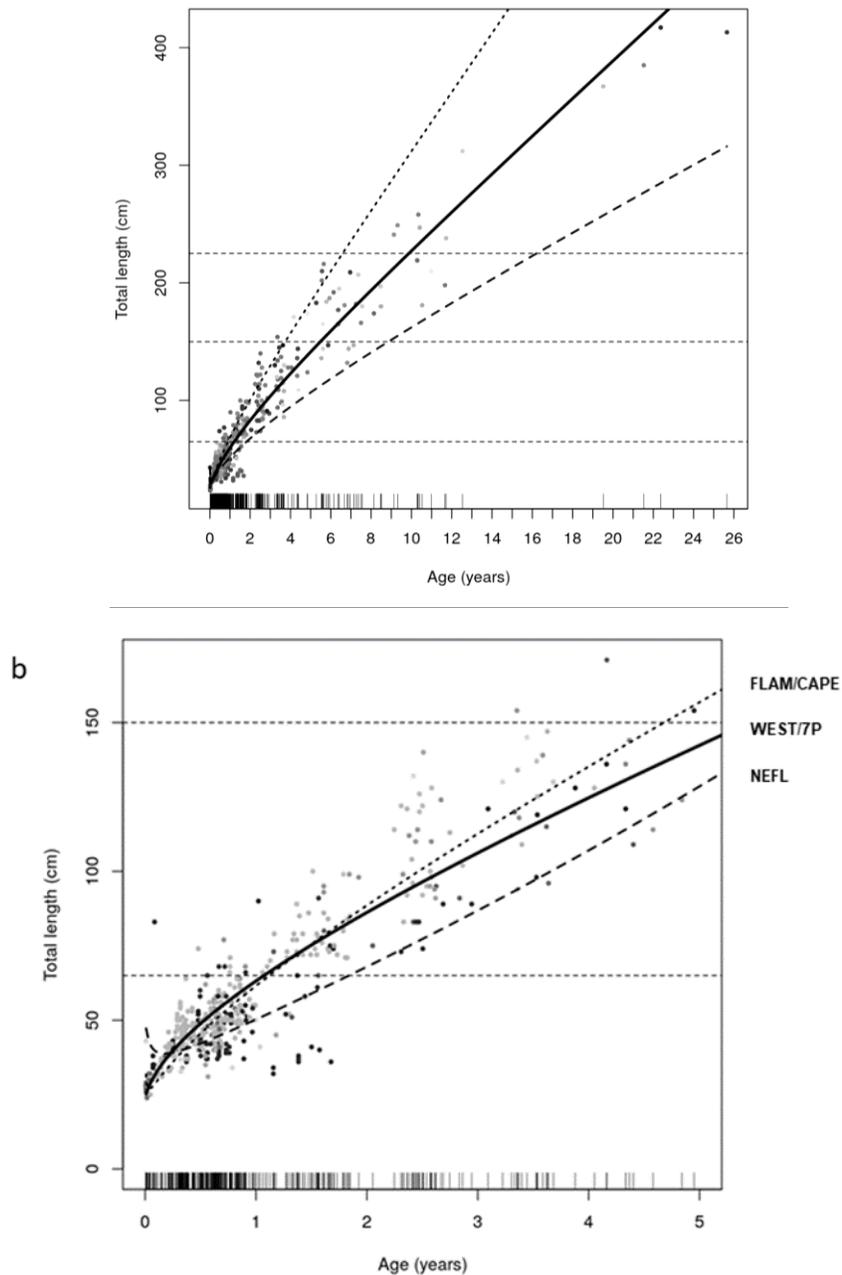


Figure 4. Growth curves for American crocodiles in response to salinity conditions in south Florida captured between 1978–2015. a) Solid line is average growth at mean salinity during the dry season, dotted line represents growth rate under low salinity conditions, and the dashed line is growth rate under high salinity conditions. b) Solid line is the average growth at the West Lakes and 7Palms area, dotted line is average growth rate at Flamingo and Cape Sable area, and dashed line is average growth rates in NE Florida Bay. From Briggs-Gonzalez et al. in prep.

CROCODILIANS (AMERICAN ALLIGATORS & CROCODILES) INDICATOR— MODIFIED (DOI LANDS ONLY)

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FISH AND MACROINVERTEBRATES INDICATOR

Summary/ Key Findings

STATUS	PREVIOUSLY REPORTED WATER YEAR 2018	WATER YEAR 2019	CURRENT WATER YEAR 2020
SYSTEM-WIDE	R	R	R* *qualified by lack of April 2020 data because of COVID-19

**The system-wide status assessment for fish and macroinvertebrates for WY 2020 must be viewed with caution because no data could be collected in April 2020 and processing of February 2020 data is delayed because of COVID-19 work restrictions. February and April are critical dry-season months and these data are influential in determining stoplight assessments in past years. Field sampling has been restarted and we hope to use hydrological analyses and modeling to correct for uncertainty in the WY 2020 stoplight in future work.*

- Fish and macroinvertebrates are important indicators in the Everglades because of their role as food for predators such as wading birds and alligators.
- Fish and macroinvertebrate density and community composition are correlated with hydrology and they integrate the effects of hydrology in all of their life stages.
- Positive or negative trends in fish and macroinvertebrate density relative to hydrological changes are correlated with trends in a restored Everglades ecosystem.
- With the implementation of one group of Everglades Restoration projects, the CEPP, we expect to see increases in density of these animals in areas where hydrological conditions are currently drier than targeted because they will become wetter (e.g., ENP Shark River Slough and Taylor Slough, northern WCA-3A, WCA-3B), and no change or decline in areas where water is currently ponded and may become drier (e.g., southeastern WCA-3A).
- The time between drying events is a key driver of fish and macroinvertebrate density and species composition. We anticipate improvement in this indicator where projects that deliver more freshwater have been implemented.
- Water quality (total phosphorus concentration) also impacts the fish and macroinvertebrate indicator. Improved water quality by maintaining historical concentrations of total phosphorus in areas receiving enrichment will thus also improve this indicator.

The Fish & Macroinvertebrates indicator remains well below the restoration target.

The fish and macroinvertebrate indicator remains well outside the restoration target (red stoplight) in Taylor Slough and Shark River Slough because the majority of Everglades Restoration projects, specifically the CEPP, that will benefit aquatic animals in these areas have not yet been implemented or are being implemented now. The status of individual fish and macroinvertebrate indicators used collectively to assess status in ENP (Shark River and Taylor sloughs) and WCA 3A and WCA 3B, were markedly (Taylor Slough) or moderately (Shark River Slough) inconsistent with the rainfall-based restoration target in WY 2019 (assessed from July 2018 through April 2019). We were unable to properly calculate the value for WY 2020 because laboratory and field work was stopped (March – April 2020) and then slowed from Covid-19 precautions. This indicator contains multiple components (total fish density, density of indicator fish species and Everglades crayfish, and non-native fish relative abundance) and those in Shark and Taylor sloughs in ENP that are sensitive to hydrological drying have been below rainfall-based expectations at most long-term monitoring sites extending back to WY 2013. This contrasts with the same indicators in WCA 3A and 3B, where they have been within or above expectations based on rainfall. There is continued evidence that Shark River Slough and Taylor Slough dried more

FISH AND MACROINVERTEBRATES INDICATOR

frequently and/or longer than required to meet our rainfall-based restoration targets, though some improvement was noted in WYs 2019 and 2020 that should be reflected in future assessments.

The regional scale relative abundance of non-native fish exceeded 2% for Shark River Slough in WYs 2015-2017 but dropped below that level in WYs 2018 and 2019, though non-native fishes remained common there. This indicator exceeded the 2% relative abundance cutoff in Taylor Slough from 2016 through 2019. Non-native fishes continue to be present in field samples from WCA 3A and 3B, but in frequency below the 2% relative abundance cutoff. Asian Swamp Eels, a non-native species common in Taylor Slough for several years, have appeared and increased in frequency in Shark River Slough and WCA 3B during this evaluation period. The relative abundance of non-native fish (African Jewelfish, Mayan Cichlids, Asian Swamp eels, and Spotfin Spiny Eels) exceeded our restoration targets in both Shark River Slough and Taylor Slough in WY 2015-2017, when we obtained strong statistical evidence that non-native fish were causing decreases in both density and biomass of native species in Shark River Slough. Native fish abundance improved in Shark River Slough in WY 2018 and 2019 data coinciding with a marked decrease in African Jewelfish density, suggesting resilience in aquatic communities in this area. Abundance of non-native fishes continue to be high in Taylor Slough with unknown long-term effects on the ability of this area to provide high-quality foraging sites for apex predators.

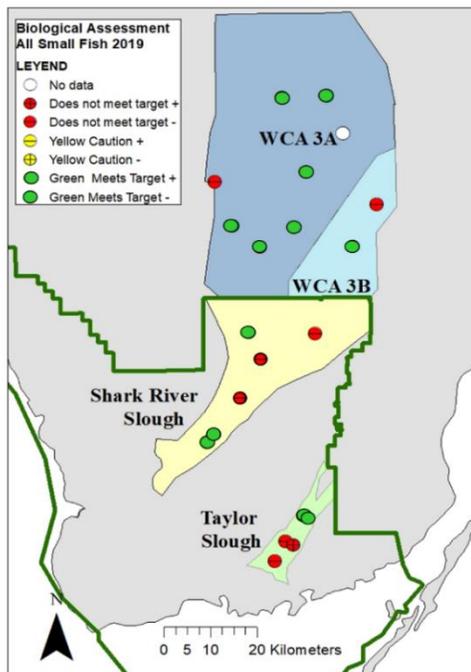


Figure 1. Spotlight colors for small fish indicator at long-term study sites in WCA 3A, 3B, and ENP. Plus and minus signs on stoplights indicate if color assigned for more or fewer fish than expected.

The density of prey-base fishes in Shark and Taylor sloughs was below rainfall-based expectations at many long-term monitoring sites in the current evaluation period (Figure 1). This condition has extended back to WY 2013. Encouragingly, there was modest improvement in Shark River Slough since the last assessment, especially for species impacted by African Jewelfish (Eastern Mosquitofish and Least Killifish). These results are in contrast to the same indicator in WCA 3A and 3B, where they have been within or exceeded expectations based on rainfall, with exceptions in far western WCA 3A and northern WCA 3B. Flagfish and Everglades crayfish densities, two performance measures sensitive to the frequency of drying, indicate marshes in Taylor Slough have been dried more frequently than expected based on our rainfall-based target (Table 1).

FISH AND MACROINVERTEBRATES INDICATOR

Table 1. Stoplight Table for Fish & Macro-invertebrates Indicator (WCA3 and ENP only) for Water Years 2016- 2020. WY 2020 is blank because data could not be collected in April of that year.

Performance Measure	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
Overall	R	R	R	R	
Shark River Slough					
Total Fish	R	R	R	Y	
Non-Native Fish	R	R	Y	Y	
Bluefin Killifish	R	Y	Y	Y	
Flagfish	G	Y	Y	Y	
Eastern Mosquitofish	R	R	R	Y	
Everglades Crayfish	R	G	Y	G	
Taylor Slough					
Total Fish	R	R	R	Y	
Non-Native Fish	R	R	R	R	
Bluefin Killifish	Y	Y	G	G	
Flagfish	R	R	R	R	
Eastern Mosquitofish	Y	R	Y	R	
Everglades Crayfish	Y	R	R	R	
Water Conservation Area 3 A					
Total Fish	Y	g	G	G	
Non-Native Fish	Y	Y	Y	Y	
Bluefin Killifish	G	Y	G	G	
Flagfish	Y	Y	Y	Y	
Eastern Mosquitofish	Y	G	G	G	
Water Conservation Area 3 B					
Total Fish	G	G	G	Y	
Non-Native Fish	Y	Y	Y	Y	
Bluefin Killifish	Y	Y	G	Y	
Flagfish	Y	G	G	G	
Eastern Mosquitofish	G	G	G	G	

The non-native African Jewelfish relative abundance averaged as high as 20% of the fish collected at some study sites in Shark River Slough between WY 2015 and 2017. Interestingly, the relative abundance of this non-native species declined, resulting in non-native fish relative abundance below our 2% cutoff in WY 2018 and 2019. In Taylor Slough, a mix of non-native species increased in density over the assessment period. Mayan Cichlid density has fully rebounded from the effects of the cold event in 2010 and their numbers are at or above those at the previous peak. Non-native eels, Asian Swamp Eels and Spotfin Spiny Eels, have dramatically increased in abundance in Taylor Slough, particularly in electrofishing catches at alligator ponds.

FISH AND MACROINVERTEBRATES INDICATOR

Though fish and macroinvertebrate density continue to be below or well below restoration targets based on rainfall in Shark River Slough and Taylor Slough, they are generally at expectations in WCA 3A and 3B. Based on simulations of historical hydrological conditions in WCA 3A, the long hydroperiods characteristic of this area today are consistent with historical expectations. However, this area currently lacks sheetflow because of hydrological compartmentalization of the area. We currently have no basis to assess the impact of lost sheetflow on fish and macroinvertebrate communities. Research in the DECOMP Physical Model suggests that a flowing Everglades may have different nutrient dynamics than in the current compartmentalized condition with implications for food-web structure and function.

The last biennial report included WY 2018 data collected through emergency water releases necessitated by large volumes of rain that fell in 2017 and created hydrological conditions close to those expected in the restored ENP wetlands of Northeast Shark River Slough and elsewhere. The dry season of WY 2018 (December 2017-April 2018) experienced relatively little rain and water recession was steep and continuous, supporting an exceptional wading bird nesting season. Wet-season fish and macroinvertebrates are a lagging indicator impacted by drying events, so the main impact of the very wet conditions in late 2017 (WY 2018) were reflected in this WY 2019 assessment (data collected wet season of calendar year 2018). This is reflected in the improved indicator values in Shark River Slough (Yellow in place of red the previous year). Similarly, some Taylor Slough indicators were red because of wetter conditions than predicted by our rainfall-driven targets (more fish than predicted). These results underscore that fish and macroinvertebrate abundance is responsive to hydrological conditions and will improve if restoration projects provide the target hydroperiods.

The most striking result in the last reporting period was evidence of a rapid decline in non-native species in Shark River Slough, following a multi-year increase. The data added since the last assessment clearly demonstrate a rebound of negatively impacted native species associated with these changes. This decline is consistent with past experience that explosive growth of non-native fish species, may be followed by a decrease in their abundance for reasons that are poorly understood, and persistence at low density but widespread distribution. Continued monitoring will be needed to determine if this optimistic scenario is appropriate for African Jewelfish in Shark River Slough. Our monitoring data provide strong empirical evidence that these non-native fishes are re-shaping the function of Everglades aquatic animal communities. How this will ultimately affect the ability of these aquatic communities to provide critical food for iconic predators, including wading birds and alligators, remains to be learned. Filling canals to depths that eliminate winter thermal refuges is currently the most promising restoration action to diminish the abundance of the non-native fishes already in the Everglades. Completing restoration of historical hydroperiods may provide greater resilience of native aquatic communities and diminish impacts of some non-native species, whose expansion and success may be facilitated by the drier environment currently prevailing because of past water allocation and delivery choices. Unfortunately, deeper conditions may facilitate other non-native species such as Peacock Bass and Oscars that thrive in lacustrine habitats.

Data and Calculations

Updates on Calculation of Indicator

There have been no major changes from past biennial reports in the way this indicator was calculated. We used a 'dynamic target' approach that models the expected value for each performance measures based on target hydrological conditions (Trexler and Goss 2009). Hydrological targets were calculated based on the relationship of rainfall and stage at our long-

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term study sites between November 1, 1993 – November 1, 1999. This period was selected because it includes the last large El Niño event that yielded two years of particularly wet conditions (1997-1998) and hydrological stages in ENP near those predicted by the Natural System Model (SFNRC 2005). This is also a period before operational changes for the Combined Structural and Operational Plan (CSOP), Interim Operational Plan (IOP), and Everglades Restoration Transition Plan (ERTP) programs. We used these hydrological targets to estimate prey-base performance measure values given the observed rainfall during the assessment period of WY 2017 (June 2015-May 2016) and WY 2018 (June 2017-May 2018).

Our overall assessment of wading bird and alligator prey is based on five performance measures: total fish density (all species of fish summed), Eastern Mosquitofish (*Gambusia holbrooki*), Flagfish (*Jordanella floridae*), Bluefin Killifish (*Lucania goodei*), and Everglades crayfish (*Procambarus alleni*). Past work has demonstrated that these fish are representative of the variety of life-history responses to drying events (Trexler et al. 2005; DeAngelis et al. 2005). Flagfish and Eastern Mosquitofish typically recover quickly from marsh drying, while Bluefin Killifish recover more slowly (DeAngelis et al. 2005). Additionally, the Everglades crayfish has been shown to survive some marsh drying conditions and is typical of short-hydroperiod marshes in the southern Everglades (Hendrix and Loftus 2000; Dorn and Trexler 2007). We analyzed these data using hydrological parameters that estimate the time passed since re-flooding from the most recent drying event. We define drying as water depth dropping below 5 cm and flooding as when previously low water levels rise above 5 cm. To account for ecological responses driven by hydrology operating at different spatial scales, we created three different hydrological parameters: local days since flooding (LDSF), local days since flooding adjusted for regional drying (ADSF), and regional days since flooding (RDSF). We also include a 'season' parameter to capture seasonal patterns of recruitment that may inflate densities from the production of juveniles that occurs primarily between April and August. We used linear regression to capture patterns of recovery following marsh flooding and evaluated our models using Akaike's Information Criterion (AIC) to select a preferred model from a hierarchy of models. Our final models generally describe the data well, although fit varies among species and regions. Stoplights are calculated to accommodate inter-site variation in model fit and uncertainty by use of the deviation of observed and target predictions (Trexler and Goss 2009). We assign red stoplights for extreme deviation of observed from expected (both above and below) in a single year or lesser deviations that are consistent in runs of previous years (3 or 5 years with consistent deviations yield red with relatively less deviations in the assessed year). We repeat the assessment using biomass (wet weight grams/meter²) to compare with results using density (individuals/m²). The results are consistent between the two methods, so we report the density values to be consistent with past reports.

This year, as in previous years, we assessed non-native species by comparing their regional relative abundance to an arbitrary value of 2%. When the entire regional collection of non-native fishes exceeds 2% of all fishes collected, a red light is assigned; yellow lights are assigned when non-native species are present in the collections but comprise less than 2% of the total; and green when no non-native fish species were collected. This year we have developed a modeling approach to link changes in performance measures that can be linked to non-native species invasions. We are currently circulating that model for discussion before including it in this formal assessment.

How these data are being used?

The data used here are collected to assess the Modified Water Deliveries Program and are used in the RECOVER Systems Status Reports and to produce the RECOVER performance measure

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documentation sheets for the Prey-based Freshwater Fish performance measure. Performance measures are planning tools used by RECOVER to determine the degree to which proposed alternative plans are likely to meet CERP restoration objectives or implemented plans have met restoration objectives. Documentation sheets provide technical information about the indicator and describe desired future conditions and how the indicator can be used for evaluation and assessment. The freshwater fish documentation sheet was approved in May 2011. This information also can be used in the context of interim goals.

This assessment uses a model-based target for assessment of current status and assigning stoplights. The same models have also been used for evaluation purposes, most recently for the Central Everglades Planning Process (CEPP) and other scenario-based evaluations of possible future Everglades conditions (USACE 2014; SERES Project 2012; Catano et al. 2015; Beerens et al. 2017).

New insights relevant to future restoration decisions

This report is hampered by delay in collection of the April 2020, precluding inclusion of WY 2020 in this report. The pandemic conditions causing that are not likely to be repeated and we will be able to add that year in the next biennial assessment. The WY 2019 data from Shark River Slough are encouraging and may bode well for benefits from major hydrological restoration activities influencing that area. Though Taylor Slough received red stoplights for most indicators, restoration activities impacting that region are also encouraging. For several years after 2000, Taylor Slough experienced very short hydroperiods that dramatically decreased fish abundance there, especially long-lived species like Largemouth Bass and Florida Gar. Their loss may have created an opportunity for non-native Asian Swamp Eels and Mayan Cichlids to thrive there as hydrological management improved. The long-term implications of these invasions is still unclear, but unlike Shark River Slough, there is no indication that non-native taxa are being replaced by native ones in Taylor Slough.

These assessments would be improved by use of hydrological targets derived from the CEPP. A long-running concern is that models used in the evaluation phase of CERP project development are not run using rainfall data collected after the project planning period. This has required us to develop rainfall-based targets from historical hydrological conditions that may not reflect the actual management targets used to select restoration plans. This assessment would be improved if CEPP-consistent targets could be made available. An important element of CEPP is to recapture water flow velocities believed to be a feature of the historical Everglades and lost in the highly managed ecosystem of today. We are gathering information that can be used to include water flow impacts on fish and macroinvertebrate performance measures. Ideally, hydrological data that we currently obtain from Everglades Depth Estimation Network (EDEN) will include flow velocity metrics and water quality in the future, permitting us to fully account for all restoration-affected environmental drivers that impact this indicator.

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PERIPHYTON INDICATOR

Summary/Key Findings

STATUS	PREVIOUS REPORTING WATER YEAR 2018	PREVIOUS WATER YEAR 2019	CURRENT WATER YEAR 2020
SYSTEM-WIDE	Y	Y	Y

- Periphyton abundance, nutrient content, and diatom algae species composition provide an important indication of the oligotrophic, or low nutrient, status of the Everglades. These three metrics are combined into a multi-metric index to provide an indication of how hydrologic management influences the inflow and downstream transport of novel and legacy phosphorus (phosphorus already accumulated in the soil).
- The multi-metric index is a combination of periphyton biomass, phosphorus concentration, and the proportion of calcareous diatom species comprising the periphyton community.
- We expect a reduction in biomass, an increase in phosphorus concentration, and a reduction in calcareous diatoms at locations experiencing above-ambient phosphorus loads. A modified index is used for the Arthur R. Marshall Loxahatchee National Wildlife Refuge, where an increase in biomass and calcareous diatoms indicates a departure from ambient conditions.
- If total phosphorus concentrations of inflowing water are lower than ambient marsh concentrations, we expect that one group of Everglades Restoration projects, the CEPP, will improve the quantity, quality, and calcareous composition of periphyton communities.

On a system-wide scale the periphyton indicator remains below the restoration target in central and northern WCA-3A and WCA-2A because these areas have not recovered from a history of higher than ambient phosphorus loading and have not received the benefits of restoration projects that have not yet been implemented. Downstream/coastal regions of Everglades National Park are below the restoration target because they are receiving increasing amounts of marine-sourced phosphorus in the absence of full-scale Everglades Restoration implementation.

The status of the modified periphyton indicator (an indicator of water quality) for greater Everglades ecosystem was below the restoration target (yellow stoplight) in WY 2016-2018 but showed improvement in WY 2019 and 2020 (Figure 1, Table 1). The system-wide status assessment for periphyton for WY 2019 was based on a combined quality, biomass, and composition metric (using periphyton total phosphorus content, ash-free dry biomass, and percentage calcareous diatoms, as previously reported). Surveys were conducted in A.R.M. Loxahatchee NWR (WCA 1), ENP [Shark River Slough (SRS) and Taylor Slough (TS)], and WCAs 2 (A & B combined) and 3 (A & B combined).

The status of the periphyton indicator was below the restoration target across all basins in WY 2019 and 2020 based on biomass (score = 84 and 81, respectively) and composition (score = 80 and 77, respectively), suggesting that biomass and the abundance of calcareous diatom species is lower than expected background levels. However, the periphyton quality score based on TP content improved in 2019 and 2020 (score = 90 and 89, respectively). There are fluctuations from year to year across basins with a significant improvement trend in WCA 2 but not the other basins (Figure 2).

PERIPHYTON INDICATOR

Sites with poor periphyton quality were clustered near the L-67 canal, south-central WCA 3A, and near canal boundaries of A.R.M. Loxahatchee NWR (WCA 1) and WCA 2A. Several sites in coastal areas also had lower periphyton quality, possibly driven by marine sources of phosphorus.

The periphyton indicator is below the restoration target.

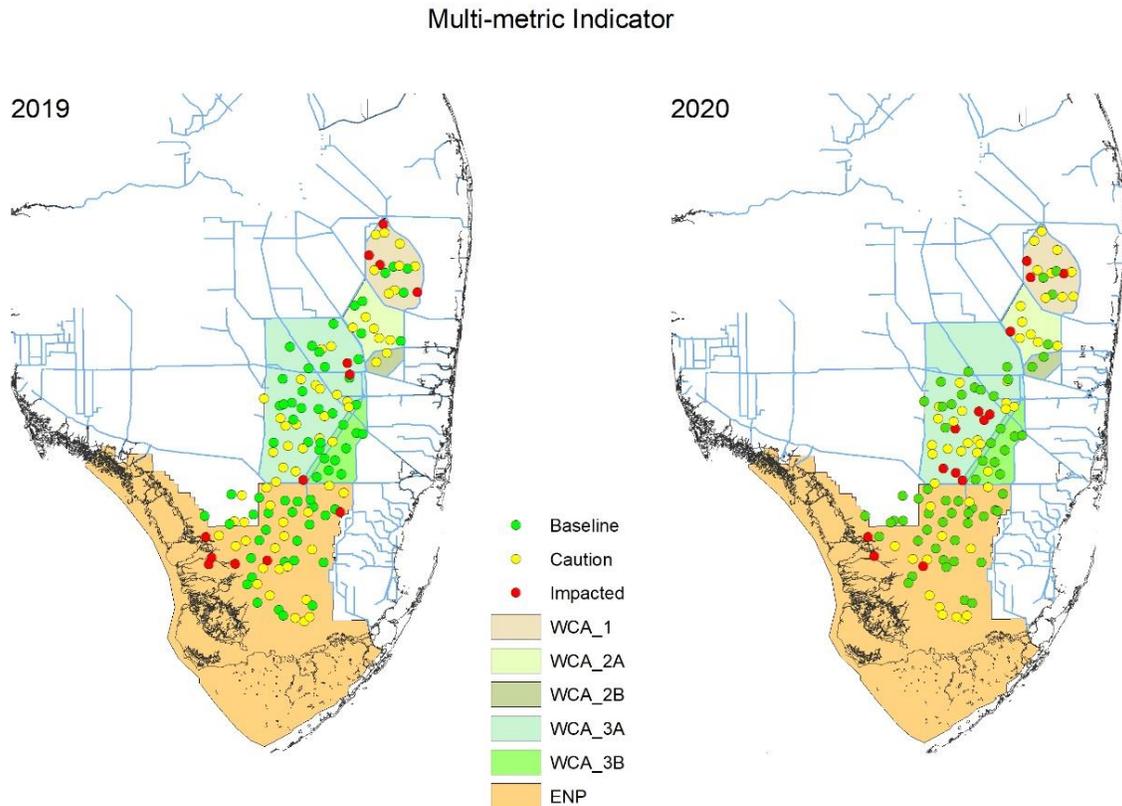


Figure 1. Stoplight colors for the multi-metric periphyton indicator for WY 2019 (left) and WY 2020 (right)

PERIPHYTON INDICATOR

Table 1. Stoplight Table for Periphyton Indicator for Water Years 2016 - 2020.

	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
SYSTEM-WIDE					
Quality (TP)	Y	G	Y	G	G
Biomass	Y	Y	Y	Y	Y
Composition	Y	Y	Y	Y	Y
Multi-Metric	Y	Y	Y	Y	Y
WCA 1 (A.R.M. Loxahatchee NWR)					
Quality (TP)	Y	G	G	Y	Y
Biomass	Y	G	G	G	G
Composition	Y	Y	Y	Y	Y
Multi-Metric	Y	Y	Y	Y	Y
WCA 2					
Quality (TP)	Y	Y	Y	G	G
Biomass	G	Y	Y	G	Y
Composition	Y	Y	Y	G	Y
Multi-Metric	Y	Y	Y	G	Y
WCA 3					
Quality (TP)	Y	G	Y	G	G
Biomass	Y	Y	R	Y	Y
Composition	Y	Y	Y	G	Y
Multi-Metric	Y	Y	Y	G	Y
SRS					
Quality (TP)	G	G	G	G	G
Biomass	Y	Y	Y	Y	G
Composition	G	Y	G	Y	G
Multi-Metric	G	Y	Y	Y	G
TS					
Quality (TP)	G	G	G	G	G
Biomass	G	Y	G	G	G
Composition	Y	G	Y	Y	Y
Multi-Metric	G	Y	G	Y	Y

PERIPHYTON INDICATOR

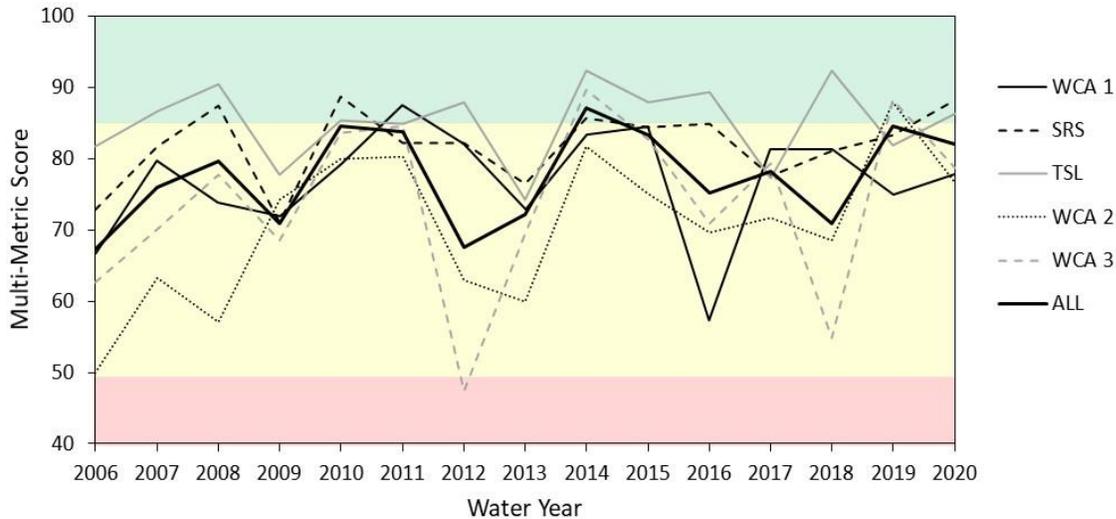


Figure 2. Time series of change in the periphyton multi-metric.

Data and Calculations

Updates on calculation of indicator

The thresholds used for the periphyton quality (reflection of TP) and quantity (biomass) metrics described above were refined from earlier experimental studies and CERP MAP data that have been collected for over a decade for the periphyton mapping program (Table 2). We used 15 years of data from each site with baseline values being within one standard deviation of the mean and caution and impacted values representing greater than one and two standard deviations of the mean. Each site is coded as baseline, caution, or impacted and assigned a 100, 50, or 0, respectively. The sites are then averaged within each wetland basin and the basin scored as baseline, caution, or impacted if the mean is ≥ 85 , < 85 and > 50 , and ≤ 50 , respectively. The compositional metric is most closely correlated with inflowing weighted mean TP concentrations at inflow structures, and this correlation remains high for sites well to the interior of the wetland. The full interpretation of the periphyton metric for marsh impairment must consider inflow and legacy TP, local biogeochemical processes, and other factors (hydroperiod, soil compaction, and subsidence) influencing periphyton ecology.

Table 2. Stoplight values for the periphyton indicator multi-metric.

Metric	Measurement	Stoplight	WCA1	WCA2A	WCA3A	SRS	TS
Quality	Total Phosphorus (ug/L)	Baseline	<500	<200	<300	<200	<150
		Caution	501-600	201-300	301-400	201-300	151-200
		Impacted	>601	>301	>401	>301	>201
Quantity	Ash-Free Dry Mass (ug/g)	Baseline	<10	>20	>10	>20	>50
		Caution	11-20	1-19	1-9	1-19	1-49
		Impacted	>21	<1	<1	<1	<1
Composition	Calcareous Diatoms (%)	Baseline	<10	>95	>95	>95	>95
		Caution	11-70	75-94	75-94	75-94	75-94
		Impacted	>71	<74	<74	<74	<74

PERIPHYTON INDICATOR

How these data being used?

These data and findings were also reported in the RECOVER 2019 System Status Report and are being used to support models for synthesis efforts. This information also can be used in the context of interim goals. We have also conducted comparative studies in other karstic wetlands in the Caribbean region and have provided this tool for use there (La Hée and Gaiser, 2012; Gaiser et al. 2015).

New insights relevant to future restoration decisions

Insights stemming from long-term analyses (Gaiser et al. 2015; Marazzi et al. 2018) suggest that periphyton is responsive to inputs of phosphorus from inflow structures at scales of meters to tens of kilometers. Average wet season values of quality, biomass, and composition for each of the basins were highly correlated with inflowing TP concentrations, suggesting high sensitivity to loads that change with water flow. This explains why wet years on record show greater impairment than dry years.

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PERIPHYTON INDICATOR

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WADING BIRDS (WOOD STORK & WHITE IBIS) INDICATOR

Summary/Key Findings

STATUS	PREVIOUSLY REPORTED WATER YEAR 2018	WATER YEAR 2019	CURRENT WATER YEAR 2020
SYSTEM-WIDE	Y	R	C

- We have pre-drainage information that shows us that large numbers of wading birds were a defining characteristic of the pre-drainage Everglades. Wading bird nesting is strongly driven by hydrology, through both production of and access to aquatic prey animals.
- With Everglades Restoration, we expect to see earlier nesting by Wood Storks, a shorter interval between White Ibis “supercolony” nesting events, a higher ratio of tactile to visual foragers, and a higher proportion of nesting concentrated in coastal areas of Everglades National Park.
- Wading bird nesting responds to system-wide, large-scale changes in water depth, hydroperiod, and seasonal patterns; therefore, the benefits of individual projects that contribute piecemeal to hydrological restoration are unlikely to be reflected in this indicator.
- Following exceptional rainfall and ideal water levels, the spring 2018 nesting event strongly suggests that restored flows and hydroperiods will result in larger nesting numbers and increased nesting success.
- In WY 2019 and WY 2020, the less than optimal hydrological conditions both for production and access to prey, resulted in low nesting numbers and late nesting. The contrast of these three years (2018, 2019, and 2020) signaled that large responses in wading bird nesting may not be consistently observed until hydrological thresholds have been reached.
- Everglades Restoration projects that restore freshwater flows to the productive southwest estuarine region are seen as key to restoring wading bird nesting.
- It is difficult to associate wading bird nesting responses on a system-wide basis with any particular project, though those that contribute the most to restoration of hydrological flows typical of the pre-drainage period are those that would be highest priority.

The wading bird indicator remains well below the restoration target because the majority of Everglades Restoration projects that will affect the overall landscape have not yet been implemented.

This indicator is built on four indicators of Wood Stork and White Ibis reproduction, all of which are based on qualitative or quantitative conditions measured in the pre-drainage period. These have to do with the timing and location of nesting (Figure 1 & 2) and the proportion of tactile feeders nesting (Figure 3) and how frequently supercolonies form.

WADING BIRDS (WOOD STORK & WHITE IBIS) INDICATOR

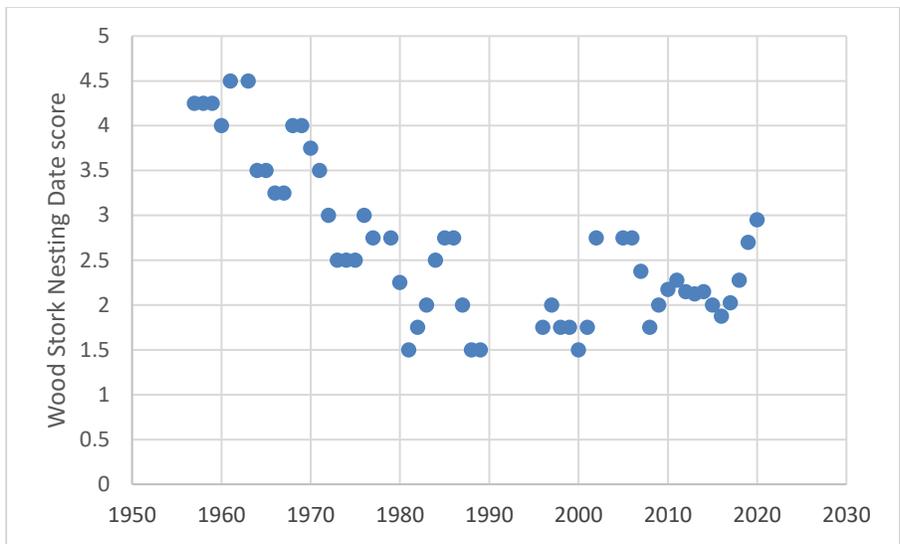


Figure 1. Wood Stork nesting initiation date score. November = 5, December = 4, January = 3, February = 2, March = 1. The target is nest initiation in November or December.

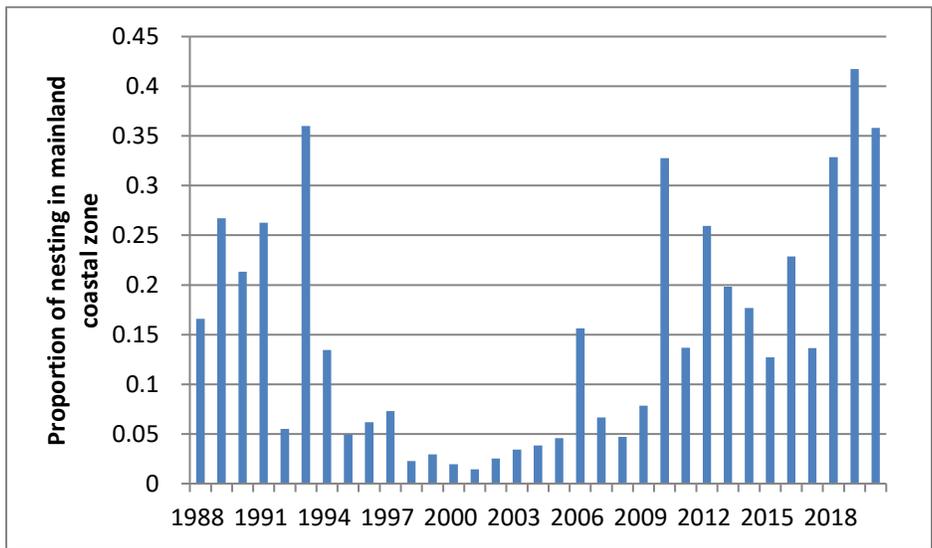


Figure 2. Proportion of wading bird nesting that occurs in the coastal zone. The target is greater than 50%.

WADING BIRDS (WOOD STORK & WHITE IBIS) INDICATOR

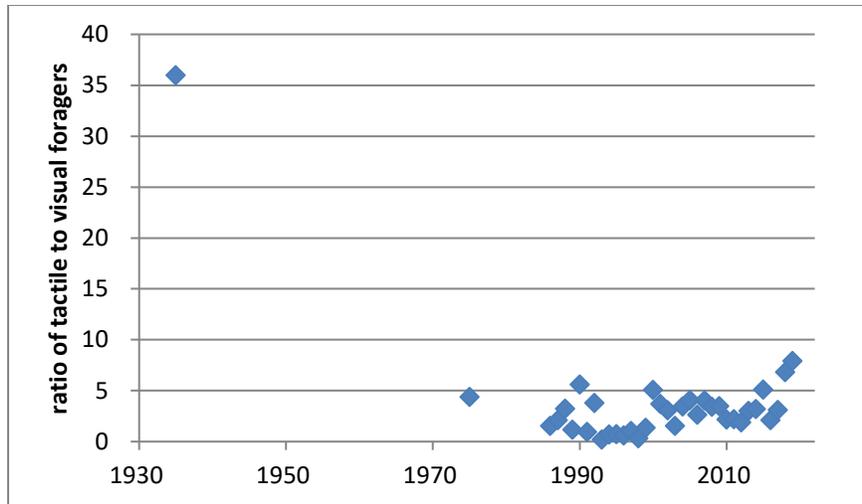


Figure 3. Ratio of nesting tactile to visual foraging wading birds in the Everglades. The target is a 30-1 ratio.

During WY's 2016 – 2020, there was highly variable response that was also highly instructive. For all years, the interval between exceptional ibis nesting years was well within the zone typical for recovered conditions. During WY 2016, the indicators were generally in the red zone, with relatively late nesting and little signs or trends of recovery.

However, the 2017 water year and spring of 2018 was marked by exceptional rainfall, deeply and broadly flooded conditions, excellent drying conditions during the nesting season, and the largest nesting since 1940. This event was extremely instructive, since hydrology was, at least briefly, close to restored conditions, all but one of the wading bird indicators increased markedly, and birds responded in a direction and fashion that was predicted by the hydrological characteristics. It is of note that birds apparently showed a massive response to hydrological change on a very short time scale (<1 yr). While the overall summary indicator only moved to yellow for that year (the first yellow in the history of this summary indicator), remember that individual year effects are muted by use of a five-year moving average for indicators.

The 2019 spring season was characterized by low nesting numbers and late nesting in part because of less than optimal hydrological conditions both for production of prey, and for access to those prey. The 2020 nesting season was even worse, with low initial water levels and widespread drying, very late nesting, low nesting numbers overall, and very low nesting success by Wood Storks. However, we have also seen a steady growth in coastal colonies in Everglades National Park, suggesting that estuarine conditions may have become more attractive over time for nesting birds there.

While these responses suggest that conditions are not improving in a dramatic way, there are two important points to be learned from the record. First, all the indicators appear to be improving gradually over time, and one (ibis supercolony) has consistently achieved the threshold necessary for the green category. Second, very positive responses by birds are predicted only with the onset of restored hydrological conditions – the low indicator readings are therefore consistent with current predictions. Especially given the 2018 spring response to markedly better hydrological conditions, confidence in this indicator as a reliable marker of restored conditions is very solid.

WADING BIRDS (WOOD STORK & WHITE IBIS) INDICATOR

The Wood Stork and White Ibis wading bird indicator remains below the restoration target.

Table 1. Stoplight Table for Wading Birds (Wood Stork & White Ibis) for Water Years 2016 – 2019. Note that the water year stops at the end April of each year, which occurs in the middle of wading bird nesting season. We have chosen to label the nesting season according to the prior water year. Hence WY 2020 does not have any nesting data yet because it would occur in spring 2021. This is a change in how we have reported the indicator in the past which was to report on the incomplete season; therefore, colors may be different than in previous reports.

	WY 2016 (spring 2017)	WY 2017 (spring 2018)	WY 2018 (spring 2019)	WY 2019 (spring 2020)	WY 2020 (Spring 2021)
Wading Bird Indicator Summary	R	Y	R	R	C
Ratio of Wood Stork + White Ibis nests to Great Egret nests	R	R	R	R	C
Month of Wood Stork nest initiation	R	Y	Y	R	C
Proportion of nesting in headwaters	R	Y	Y	Y	C
Mean interval between exceptional Ibis nesting years	G	G	G	G	C

WADING BIRDS (WOOD STORK & WHITE IBIS) INDICATOR

Data and Calculations

Updates on Calculation of Indicator

Because the water year stops at the end of April each year, which occurs in the middle of wading bird nesting season, we have chosen to label the nesting season according to the prior water year. This is a change in how we have reported the indicator in the past which was to report on the incomplete season; therefore, colors may be different than in previous reports. This is why WY 2020 does not have any nesting data yet because it would occur in spring 2021 and will be reported in the next report.

How have these data been used?

The information that results in these indicators is reported annually in the publicly available South Florida Wading Bird Nesting Report published by the SFWMD. This outlet is quite popular with the media and is an important tool for communicating up to date results with the public and decision makers. This information is also used in weekly operations decisions at the District. Foraging and nesting information also goes into predictions about future nesting years, usually in December or January of each year (U.S. Geological Survey and SFWMD). In July 2018, ENP sponsored a public meeting to disseminate information about the exceptional 2018 nesting season and what it meant for Everglades restoration.

New insights relevant to future restoration decisions

1. WADEM Models developed by James Beerens and collaborators at Florida Atlantic University (Beerens et al. 2015) have shown increasing ability to predict foraging and nesting based on antecedent hydrology and relationships between fish abundance and drydown interval. This work is of direct importance because it tests some of the long-held assumptions underpinning a predictive relationship between hydrology, food production, and nesting success. During the 2017 and 2018 nesting seasons these models have done well at predicting annual nesting effort.
2. Just as these relationships between nesting and hydrology are being firmed up, there is increasing awareness that predation, long a minor factor in nesting success, might be an important consideration because of the increase of Burmese pythons. Evidence from trail cameras aimed at nests suggests pythons have 5X times the effect of native nest predators on wading birds (Orzechowski et al. 2019). This suggests that in the future, nest predation could be as important as hydrology in determining nest success, which is an important consideration for the expectations of hydrological restoration.
3. Recent research has illustrated a strong positive relationship between nesting wading birds and alligators within the colony. Alligators get substantial nutrition from dropped chicks and appear to protect the colony from predation by mammals (Nell et al. 2016). In this light, declines in alligator populations and alligator condition (this report) should be seen as a threat to wading bird nesting populations.
4. Mercury has long been a contaminant of concern in the Everglades, and despite widespread declines in exposure throughout the system in the late 1990s, important pockets of exposure persist. Recent studies indicate that the net effect of mercury on reproduction can be high on both numbers of nests initiated, and nest success. Both processes are mediated through food – at high food availability, the effects of mercury are very small, but increase with declining food (Zabala et al. in press).

WADING BIRDS (WOOD STORK & WHITE IBIS) INDICATOR

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SOUTHERN COASTAL SYSTEMS PHYTOPLANKTON BLOOMS INDICATOR

Summary/Key Findings

STATUS	PREVIOUSLY REPORTED WATER YEAR 2018	WATER YEAR 2019	CURRENT WATER YEAR 2020
SYSTEM-WIDE	R	Y	Y

- Phytoplankton blooms, commonly called algal blooms, are an indicator of water quality. In the context of Everglades Restoration, the bloom indicator is cautionary, helping to ensure that restoration actions cause no indirect harm to coastal ecosystems via water quality degradation.
- We expect that implementation of Everglades restoration projects will not degrade and may indeed improve water quality conditions because restored plant communities and soils are expected to increase nutrient uptake and retention in Everglades wetlands and estuarine seagrass beds.
- However, unlike other indicators where we expect to see continual improvement, our expectation with the algal bloom indicator is that the frequency of red, yellow and green scores will not change due to Everglades Restoration projects that affect coastal ecosystems are implemented. In other words, we expect to “do no harm”.
- There was improvement in algal bloom indicator scores in the entire Southern Coastal System (SCS) region (Ten Thousand Islands to Biscayne Bay) since the 2018 reporting, when the indicator system-wide was red and well below the restoration target, reflecting impacts of seagrass die-offs and Hurricane Irma. This category 4 hurricane strongly impacted south and southwest Florida in September 2017, mobilizing nutrients in the Everglades watershed and estuaries via strong winds, storm surge, and rainfall. Watershed nutrients derived from plants (especially mangroves) and soils likely were transported to coastal waters. Additional nutrients derived from anthropogenic sources in developed areas likely were transported to downstream estuaries (e.g. to northern and central Biscayne Bay). The hurricane’s forces also mobilized internal estuarine nutrient pools, largely from seagrass beds and sediments. Seagrass detritus from Florida Bay’s 2015-2016 seagrass mass-mortality event likely released a pulse of nutrients with hurricane disturbance. Increased nutrient availability in coastal waters, derived from these watersheds and the internal estuarine sources, spurred and sustained algal blooms in 2017 and 2018.
- Improvements since WY 2018 were most dramatic in Florida Bay, in which all four subregions had good (green, above target) bloom indicator scores in WY 2020, a result not seen since WY 2009. However, Biscayne Bay conditions remain a concern, with the central bay having persistent poor indicator scores.
- Improved Southern Coastal System conditions reflect a recovery from the seagrass mortality events and hurricane impacts described in the 2018 report and above.
- This ecological recovery in the Southern Coastal System coincided with implementation of the Modified Water Deliveries Project Incremental Tests and several Everglades Restoration projects, including the C-111 Spreader Canal Western Project and Biscayne Bay Coastal Wetland Project Phase 1. This suggests that the projects’ operations are not causing harm via coastal water quality degradation and algal blooms.

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The algal bloom stoplight indicator in the Southern Coastal System (SCS) applies to the estuarine and coastal waters from Biscayne Bay to Florida Bay to the Ten Thousand Islands. Indicator scores showed improvement in water years (WY) 2019 and 2020, compared to WY 2018 (Figure 1). Scores in WY 2018 were the poorest since WY 2006 (Table 1), in large part caused by the disturbance of Hurricane Irma in September 2017 (in WY 2018). Algal blooms commonly occur after hurricanes, because these storms mobilize nutrients from coastal sediments, watersheds, and wetlands. Hurricane Irma caused mass mortality of mangrove trees from the north-central Florida Bay coast to the Ten Thousand Islands. The release of nutrients from decaying trees and destabilized coastal wetland soils, combined with residual nutrients from the 2015-2016 seagrass die-off in Florida Bay, likely fueled subsequent algal blooms. However, recovery appeared to be rapid in coastal waters in WY 2019 and 2020.

Improvements were most dramatic in Florida Bay, where all four subregions had good (green, above target) bloom indicator scores in WY 2020, a result not seen since WY 2009 (Table 1). Only central Biscayne Bay continued to have poor scores (red, well below target) scores. Biscayne Bay water quality conditions remain a concern, as persistent poor indicator scores have occurred since 2014, pre-dating Hurricane Irma and indicating potential nutrient enrichment from the local watershed. No good (green) indicator scores have been found in Biscayne Bay over the indicator's period of record (since 2005). This means water quality throughout Biscayne Bay has remained degraded from the pre-2005 baseline for the past 15-years.

Operational restoration projects are closest to three SCS subregions, SBB, BMB, and NEFB. Incremental Tests of the Modified Water Deliveries and C-1111 South Dade projects, along with CERP's C-111 Spreader Canal Western Project, ran concurrently from WY 2016 through WY 2020 and could have affected NEFB and BMB. Most algal bloom indicator scores in these subregions were green during this time and there was a rapid rebound from red to green scores between WY 2018 and 2020 in NEFB (Table 1). This suggests that operation of these two projects caused no harm to downstream estuarine water quality. The Biscayne Bay Coastal Wetland (BBCW) Project Phase 1 has operated since WY 2013 and could have affected SBB. Except for WY 2014, all algal bloom indicator scores since BBCW operations began have been yellow, similar to pre-project scores (Table 1). This suggests that BBCW has not caused harm to SBB water quality. Future CERP projects, notably CEPP and WERP, have potential to affect more westerly sub-regions (NCFB, WFB, MTZ, SWFS) of the SCS and the algal bloom indicator will serve as an important sentinel of any potential harm the projects could cause.

Algal Bloom Indicator Overview. The algal bloom indicator, described in Boyer et al. (2009), is based on the concentration of chlorophyll *a* in the water column, which is a proxy for phytoplankton biomass and typically reflects overall water quality. The indicator's target is to sustain long-term chlorophyll *a* concentrations in SCS waters at or below the median concentration of these waters during a pre-CERP reference period (early-mid 1990s through 2004). In essence, the target is for restoration actions to "do no harm" to SCS water quality. The indicator's stoplight scoring categories correspond to each sub-region's observed annual median chlorophyll *a* concentrations being below the reference period median of that sub-region (green), or from its reference period median to 75th percentile (yellow), or above its reference period 75th percentile (red).

Biscayne Bay. Biscayne Bay water quality conditions remain a concern, as the bay's bloom indicator results from the last 16 years (sub-regions NBB, CBB, and SBB in Table 1) have all been yellow or red, meaning that annual median scores in the bay have shifted to a state with more chlorophyll *a* than occurred during the indicator's reference period (calendar years 1993 through

SOUTHERN COASTAL SYSTEMS PHYTOPLANKTON BLOOMS INDICATOR

2004). The most pronounced shift was in the central and northern bay, with 11 of 14 stoplight scores being red in the past 7 years, following a 9-year period when only 1 of 18 scores was red. These persistently poor scores likely indicate that nutrient enrichment from the local watershed has stimulated algal blooms.

Florida Bay. Good (green indicator) conditions have been common in Florida Bay over the indicator's 16-year period of record. Green scores have been most common in the western and north-central bay (WFB, NCFB), but periods of 12 and 8 successive years with green scores ended following the seagrass mass-mortality event of the summer and fall of calendar year 2015 (WY 2016), which occurred only in these two sub-regions. The timing of chlorophyll *a* concentration increases in these sub-regions is consistent with the die-off being a local cause of phytoplankton blooms. Algal blooms in Florida Bay subsequently appeared to be stimulated by Hurricane Irma's disturbance, with chlorophyll *a* concentrations hitting record high values at almost all north-central and western bay sampling sites. Irma's strongest influence appeared to be in these seagrass die-off areas and the northeastern bay, and weakest influence in the southern bay. These patterns are consistent with the storm's influence being driven by high watershed rainfall and flow increasing the export of wetland nutrients to the bay, as well as the mobilization of nutrients already resident in the bay (especially in areas with dead seagrass).

Mangrove Transition Zone and Southwest Florida Shelf. Concerns persist regarding the state of the southwest Florida shelf (SWFS), where no green indicator scores have been found over the last 16 years (Table 1). Hurricane Irma appeared to impact the waters along the southwest Florida coast, with offshore waters (in SWFS) having a poor (red) indicator score and nearshore and inland waters of the Mangrove Transition Zone (MTZ) having a cautionary (yellow) in WY 2018 (Table 1). The MTZ sub-region's WY 2018 median chlorophyll *a* concentration was the highest since the reference period. However, both of these zones rebounded by WY 2020 with a green score in the MTZ and yellow score in the SWFS.

The Southern Coastal Systems Phytoplankton Blooms Indicator is below restoration targets, with an overall yellow score, but showed improvement since the 2018 reporting.

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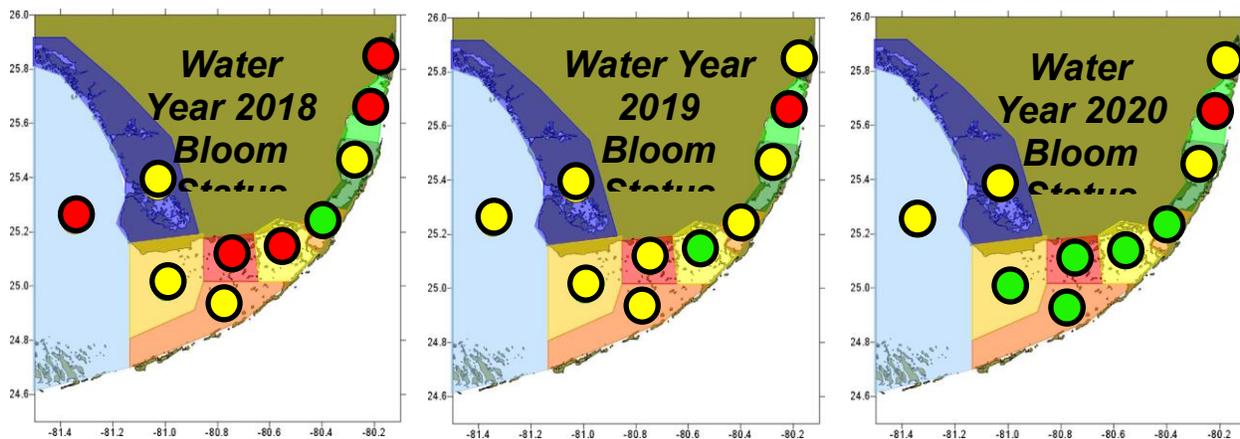


Figure 1. Map showing the spatial distribution of the water quality indicator scores improving throughout the SCS from WY 2018 through WY 2020.

SOUTHERN COASTAL SYSTEMS PHYTOPLANKTON BLOOMS INDICATOR

Table 1. Florida Bay and lower southwest coast algal bloom indicator stop-light scores, based on Boyer et al. 2009. Green results are considered good, red are considered very poor, and yellow are cautionary. Results are derived from chlorophyll *a* concentrations, which have been measured by SFWMD, the Miami-Dade Department of Environmental Management (DERM), and National Oceanic and the Atmospheric Administration (NOAA) monitoring programs. The number of stations and frequency of sampling per sub-region were not constant through the period of record shown here. Sub-regions shown are: Southwest Florida Shelf (SWFS); southwestern mangrove transition zone (MTZ) from Whitewater Bay to Cape Romano; western Florida Bay (WFB); southern Florida Bay (SFB), north-central Florida Bay (NCFB); northeastern Florida Bay (NEFB); Barnes Sound, Manatee Bay and Blackwater Sound (BMB); southern Biscayne Bay (SBB); central Biscayne Bay (CBB); and northern Biscayne Bay (NBB). Years shown in black (B) had insufficient data for reliable reporting. The System-Wide score represents the median annual condition of the set of sub-regions, without spatial weighting and tie-breaking to the poorer, more cautionary score.

WATER-YEAR	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020
SYSTEM - WIDE	G	R	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	R	Y	Y
SWFS	R	R	R	Y	R	Y	R	R	B	B	Y	Y	Y	R	Y	Y
MTZ	G	Y	Y	G	Y	Y	Y	Y	Y	Y	G	G	G	Y	Y	G
WFB	G	G	G	G	G	G	G	G	G	G	G	G	Y	Y	Y	G
SFB	G	Y	Y	R	G	Y	G	G	G	G	Y	Y	G	Y	Y	G
NCFB	G	Y	Y	G	G	G	G	G	G	G	G	Y	Y	R	Y	G
NEFB	G	R	Y	Y	G	G	Y	Y	R	Y	G	G	G	R	G	G
BMB	G	R	R	R	G	G	Y	Y	Y	Y	Y	Y	G	G	Y	G
SBB	Y	R	R	Y	Y	Y	R	Y	Y	R	Y	Y	Y	Y	Y	Y
CBB	Y	R	Y	Y	Y	Y	Y	Y	Y	R	R	R	Y	R	R	R
NBB	Y	Y	Y	Y	Y	Y	Y	Y	Y	R	R	R	R	R	Y	Y

Data and Calculations

Updates on calculation of indicator

Calculation methodology for the SCS algal bloom indicator remains unchanged from the description in Boyer et al. (2009), but indicator results have been affected by decreases in the number of field sample sites, changes in sample site locations, decreased sampling frequency, and changes in analytical methods. The stoplight threshold chlorophyll *a* concentrations for the SWFS sub-region were recalculated for this report and the previous (2018) report because Boyer et al. (2009) merged data collected at two sets of stations [by Florida International University (FIU) and by NOAA], but FIU station sampling ended in WY 2008. For this report and the 2018 report, only NOAA data from WY 1998-2004 were used to recalculate the reference period thresholds that define stoplight categories, and only NOAA data were used to assess SWFS bloom conditions from WY 2005-2020.

The effects of other sampling and analytical changes have not been thoroughly analyzed. Most of the station and sampling frequency changes occurred between 2010 and 2012, so confidence in consistency is higher for the results within the past 8 years, and results prior to 2010, than confidence in the consistency of results between these two periods. No obvious change in the chlorophyll *a* concentration patterns occurred around 2011.

How are these data being used?

The occurrence of algal blooms in south Florida coastal waters has drawn strong public attention in recent years. Blooms along the southwest coast (including red tides), in Florida Bay, and in Biscayne Bay have been a public concern. The data presented here provide an easily understood indicator of bloom status throughout these southern coastal waters. The underlying data have been used to track the status and trends of these systems and gain insight of bloom causes and effects. Most importantly, the data are providing insight of how potential restoration actions can directly (e.g., via nutrient loading from the watershed) or indirectly (e.g., via affecting the health or mortality of seagrass beds) affect the frequency, spatial extent, intensity, duration and ecological effects of blooms. To date, the data suggest that Everglades Restoration foundation projects and CERP project implementation in the southern Everglades have had no negative impacts on the SCS. The results have pointed toward the importance of major storm events as drivers that strongly influence algal bloom dynamics concurrently with anthropogenic drivers.

New insights relevant to future restoration decisions

Long-term water quality monitoring data and the results of this report not only show the susceptibility of coastal waters to conditions producing algal blooms, but also the resilience of these systems. Biscayne Bay appears to have changed its ecological state over the past 15 years, with increased phytoplankton biomass. This change has been most apparent in the central and northern bay over the past 7 years. This finding, combined with observations of increased macroalgae and seagrass die-off in these Biscayne Bay sub-regions, likely indicate increased and likely continuing nutrient enrichment. These increases in nutrients and chlorophyll *a* are most pronounced near the coast and in areas with restricted circulation, suggesting they are coming from increased watershed nutrient loading. The exact source is unclear but may be related to local urban land use or local sea-level rise effects on local nutrients, especially via ground-water changes. Restoration projects affecting water inputs to Biscayne Bay (especially BBSEER) should be aware of these uncertainties. Research to identify causes of changing Biscayne Bay water quality and potential management actions for improving the Bay is needed.

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Recent Florida Bay phytoplankton blooms appear to have been related to the health of seagrass beds and hurricane disturbance. In the decades following the late 1980s and early 1990s seagrass die-off event, seagrass recovered and algal blooms decreased, yielding good algal bloom indicator scores from WY 2005 to WY 2015 (Table 1). However, following another seagrass die-off event in WY 2016 and then a major hurricane, intense blooms occurred. Extremely high salinity conditions in the summer of 2015 contributed to initiating the die-off and Everglades restoration is expected to decrease the risk of high salinity stress in the future. Sustaining the health of seagrass beds appears to be a key to sustaining good water quality in Florida Bay, and seagrass community health has been identified as a key CERP target. It is notable that the Florida Bay ecosystem has shown strong resilience, rebounding after seagrass die-off events and after hurricane-induced algal bloom events. Good algal bloom indicator scores in WY 2020 provide a positive indicator of the bay's overall resilience.

Recent research has also indicated that sustaining the health of the coastal wetland's plant community and soils is likely a key to protecting the water quality of the southwest coast's mangrove transition zone and coastal waters. Sea-level rise is a threat to this region, with saltwater intrusion potentially causing peat collapse and nutrient releases from the wetland. Implementation of the Modified Water Deliveries Project to ENP and CEPP, combined with the operation of upstream stormwater treatment areas, can mitigate this threat.

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Summary/Key Findings

STATUS	PREVIOUSLY REPORTED WATER YEAR 2018	WATER YEAR 2019	CURRENT WATER YEAR 2020
SYSTEM-WIDE	Y	Y	Y

- Submersed aquatic vegetation (SAV) is a critical component of the Florida Bay ecosystem providing habitat, nursery, nutrient removal, sediment stabilization, and aesthetic functions and is a major economic driver of Keys’ tourism and recreation. *Thalassia testudinum* (Turtlegrass), *Halodule wrightii* (Shoalgrass), and *Syringodium filiforme* (Manatee grass) form the basis of Florida Bay’s seagrass community.
- The SAV community has been threatened in recent decades by a confluence of factors, most prominently high salinity and reduced water clarity, that kill *Thalassia*, leading to large denuded areas of bay bottom in what is known as “die-off.” A major die-off occurred in 1987 and another in 2015 when very low freshwater discharge from the Everglades allowed bay salinity to increase to in excess of 70 in some areas, twice that of natural seawater, eventually harming over 25,000 acres of *Thalassia* beds.
- A goal of Everglades Restoration projects, particularly the C-111 Spreader Canal Project and the Florida Bay Plan, is to divert more freshwater into Florida Bay from the Everglades in a way that is consistent with historical, pre-drainage hydrology. The primary objective is to improve the health and long-term vigor of the SAV community by reducing high salinity events.
- Since 2015, SAV in Florida Bay has been impacted by a series of destructive events: severe drought leading to prolonged hypersalinity that then caused seagrass die-off; direct hits from Hurricane Irma and other destructive tropical storms in 2017 and 2018; and nutrient enrichment that caused prolonged algal blooms. The 2018 System-wide Indicators Report for Florida Bay reflected this condition with an overall yellow score for SAV, including cautionary status in three of five zones and green in only two. The overall score for the bay is determined by the lowest of the zone scores.
- In 2019, conditions for SAV improved to green in the central region, though the bay-wide status indicator remained yellow owing to continuing yellow scores in two of the five zones.
- The status for SAV in 2020 again reflects a yellow overall score with the same zone scores, though environmental conditions continue to improve slowly as algae has declined, bay waters have cleared, and salinity remains in a normal range.

The overall status of the Florida Bay SAV indicator is below the desired restoration target. The indicator is yellow or fair for both WY 2019 and WY 2020, continuing a years’-long pattern where one or more zones are in only fair condition. The Composite Index summarizes SAV status for five zones of the bay and indicates that the condition of seagrass remains below targets at yellow in the Transition and Southern zones for both 2019 and 2020 (Figure 1) and green in the Northeastern, Central and Western zones. This current reporting period tracks the ongoing recovery from the die-off event in 2015 and following the passage of Hurricane Irma in September 2017 and two storms in 2018. Hypersalinity-related die-off occurred only in parts of the bay, primarily the western Central zone and in the Western zone, while the hurricane impacted the entire bay, extirpating seagrass and increasing nutrients, turbidity and algal blooms bay-wide.

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Underlying indicators reveal that recovery is occurring in some areas of the bay, while other areas are of continuing concern.

The Florida Bay SAV indicator remains below the restoration target.

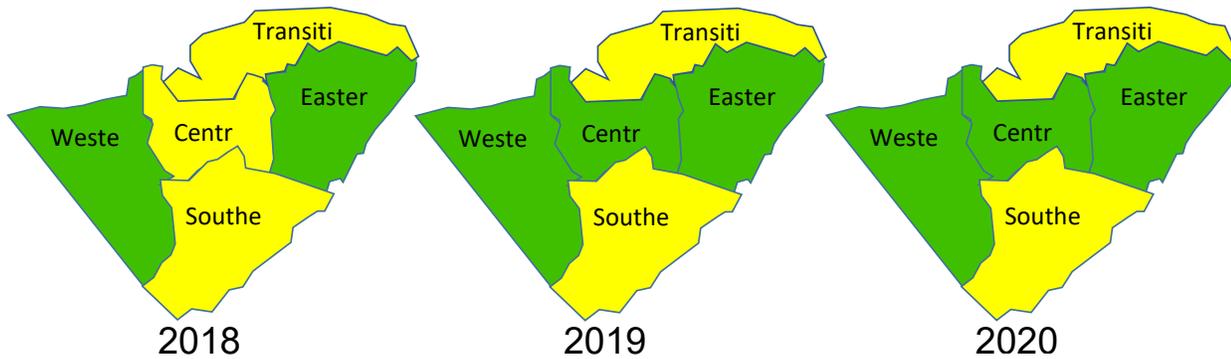


Figure 1. Overall SAV status scores for each Florida Bay zone for WY 2018-2020

UNDERLYING INDICES OF ABUNDANCE AND DIVERSITY

The Composite Index is composed of two underlying indices: the Abundance Index, which measures spatial coverage and density, and the Diversity Index, which is composed of measures for species diversity and the presence of ecologically valuable species. The Abundance Index (Index A) was poor in the Southern Zone in WY 2019 and WY 2020, fair in the Transition, Central, and Western Zones and good only in the Northeastern Zone (Table 1), matching a pattern ongoing since 2017. While the underlying data show that there is satisfactory (green status) areal cover of SAV on the bay bottom in all zones, measures of plant density are well below targets which reduces the overall Abundance Index score in most zones. Areal cover of seagrasses has nearly completed recovery from the die-off where only one basin, Highway Creek, is at yellow status and all others are green. Status of the density indicator was uneven in WY 2019 and WY 2020. Although density in many individual basins had declined following the die-off, several, including Barnes, Eagle Key, Little Madeira, and Long have returned to green status. The density status in Rankin Lake, the center of the area worst hit by die-off, has remaining yellow for three years, up from red in 2017. Johnson Key Basin had improved to green in 2018 and 2019 but fell back to yellow in 2020, showing signs of continued die-off. It joins Alligator, Trout Cove and Little Blackwater in regressing to yellow. The reason for the density decline in the latter two sites is unknown and likely not related to die-off as these basins have never displayed symptoms of die-off. The net effect of the low density is that as of WY 2020, four of the five zones are below targets for abundance.

The Diversity Index (Index B) showed improvements in some areas in recovery from the impairments of 2015-2017. Diversity status improved from yellow to green in the Northeast and Central zones in WY 2019 and WY 2020, remained yellow in the Transition and Southern zones and remained green in the Western Zone. In WY 2018 the underlying species diversity sub-index had been red almost everywhere and yellow in the Western zone. In the current period, the species diversity sub-index improved to yellow in the Northeast and Central zones, remaining red in the Transition and Southern zones and yellow in the Western zone. The Target species sub-

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index underlying Index B showed improvement as well in the Northeast zone, joining the Central and Western zones in green status. The Transition zone remains in yellow status for Target species following the negative impacts of the 2017-2018 storms. The Southern zone continues a multi-year pattern of yellow status, having improved from red in 2008.

At the basin scale in WY 2019 there were small improvements in diversity as five basins, Barnes, Trout Cove, Oyster Bay, Whitewater Bay and Johnson Key, improved to or remained green, an increase from two basins at green status the prior year. The other basins were evenly split between yellow and red status. The Species diversity sub-index is the most challenging metric for Florida Bay as green status rarely occurs. Only Whitewater and Oyster Bays are green for diversity on a consistent basis and following improvement in WY 2019, in WY 2020 Barnes and Trout Cove backslid to yellow so that currently only three basins have green status for species diversity. The other sub-index for Index B, the presence of target species, showed mixed improvements for WY 2019-WY 2020 as status improved to green in Blackwater, Eagle Key, Madeira, Long Sound and Trout Cove. The target species sub-index declined in Manatee, Little Madeira, Rabbit Key and Twin Key, which turned from yellow to red, joining Calusa Key, Alligator Bay and Davis Cove in red status. The remaining basins were about evenly split between yellow and green status.

OVERALL STATUS AND LONGTERM TRENDS

In the past decade, incremental gains in the quality of SAV habitat over several years were reflected in generally improving scores in the late 2000's and early 2010's to the point where the SAV community could be said to have finally largely recovered from the die-off of the mid-1980's. Aided especially by the wetter years of 2012 and 2013, the lower salinities improved SAV community health in many areas of the bay. These improvements were reversed by the drought in 2015 resulting in another major die-off event that year that began in June 2015 and intensified through December with major losses of SAV in parts of the Central, Southern and Western zones. However, both the hypersaline condition and most of the die-off was curtailed by the very wet dry season and cooler temperatures of WY 2016 and the el Niño rains continuing into WY 2017 which brought freshwater to the bay, effectively halting the die-off. Although active die-off has been observed in small areas of the western bay in WY 2019-20, the greater bay continues to improve despite temporary setbacks to the SAV by powerful storms. Two major algal bloom events in 2017 and 2018 subsided within about eight months and improving water clarity has allowed SAV recovery to continue. Recent indications are that SAV regrowth is occurring and may show more favorable status in the next indicator report, barring additional negative climatological events.

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Table 1. Stoplight Table for Florida Bay Submersed Aquatic Vegetation, Abundance (Index A), Diversity (Index B) and Overall (Index C) for Water Years 2016- 2020.

	WY 2016*	WY 2017	WY 2018	WY 2019	WY 2020
BAYWIDE OVERALL	Y	Y	Y	Y	Y
NORTHEAST ZONE					
Overall	G	G	G	G	G
Abundance	G	G	G	G	G
Diversity	G	Y	Y	G	G
TRANSITION ZONE					
Overall	Y	Y	Y	Y	Y
Abundance	Y	Y	Y	Y	Y
Diversity	Y	Y	Y	Y	Y
CENTRAL ZONE					
Overall	Y	G	Y	G	G
Abundance	Y	Y	Y	Y	Y
Diversity	Y	G	Y	G	G
SOUTHERN ZONE					
Overall	Y	Y	Y	Y	Y
Abundance	R	R	R	R	R
Diversity	Y	Y	Y	Y	Y
WESTERN ZONE					
Overall	G*	G	G	G	G
Abundance	Y*	Y	Y	Y	Y
Diversity	G*	G	G	G	G

**Index scores were recalculated for the Western Zone in WY 2016 based on supplementary data following seagrass die-off.*

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Data and Calculations

For WY 2019 the overall SAV indicator showed a continued yellow status for the bay as in previous years, falling short of restoration targets in several metrics and geographic areas. While holding steady in some sectors, in WY 2020 the SAV community showed decline in the Transition, Central and Western bay relative to prior years' status. Repercussions of the die-off and tropical storms continued as the bay status backslid for two years prior to this reporting period. This reflects the legacy effect of both die-off and windstorm damage as nutrients were elevated in the bay for months following the events, impacting water clarity, photosynthesis and regrowth. Nutrients and clarity returned to "normal" levels during this reporting period in 2019. While the indexes improved slightly in 2019 and 2020, the recovery is a work in progress.

Updates on calculation of indicator

The basic methodology for calculating the SAV Indicator, underlying Indexes and component scores for SAV are detailed in Madden et al. 2009. Status indicators for SAV are calculated each year based on annual Braun-Blanquet surveys conducted each May under auspices of the Fish Habitat Assessment Program (FHAP), funded by SFWMD. Scores for each of four SAV metrics are calculated to summarize the status and trends of benthic vegetation in Florida Bay. Two underlying metrics are combined to form the Abundance Index (Index A), comprised of Spatial extent and Density components. Two underlying metrics are combined to form the Diversity Index (Index B), comprised of the Species diversity and Target species components.

Scores are normalized to a 0-1 scale and compared against pre-established ranges for each metric indicating poor (red), fair (yellow) and good (green) status based on historical data and desired performance targets. Score ranges are set for each of five zones in the bay based on history and expectation for recovery and all basins in a zone are averaged to give a zonal average for the sub-indices and Indexes. Scores from each zone are combined to create Index C, the overall score for the zone. For the bay as a whole, a single system status indicator is taken as the minimum composite score from the five zones. That is, the bay-wide score is determined by the lowest Index C zone score. The rationale for this step is that the entire bay should assume the lowest score rather than an average which would always bias the status positively. Our aim is that the most conservative assessment should characterize the bay for restoration applications and that if all five zones are not green, it is important that a lower indicator flag the bay as requiring monitoring, management attention and restoration action.

How are these data being used?

Data from the indicator analysis were used in a variety of ways in 2019-20: to communicate SAV status internally within the SFWMD and to its Governing Board and to the Water Resources Analysis Coalition; to communicate with research collaborators and interagency partners, including USGS, NOAA, DOI, FDEP, Miami-Dade DERM, ENP, USEPA, RECOVER and others; to provide a visual status report to Congress and to the public via presentations; to formally document and report SAV status in such publications as the 2019 South Florida Environmental Report, the 2019 System Status Report, the 2019 and 2020 C-111 Annual Ecological Reports, the C-111 Spreader Canal Western Features Project Monitoring and Assessment Report, the Minimum Flows and Levels (MFLs) for Florida Bay Review and Update report and other published documents.

The indicator and components are continuously used to evaluate progress in and success of restoration activities in the southern Everglades and Florida Bay. The MFL rule for Florida Bay (SFWMD 2006, 2014) establishes minimum acceptable water delivery from the watershed

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needed to maintain downstream SAV habitat, particularly *Ruppia* (Strazisar et al. 2013a) in the Transition Zone and *Thalassia* and *Halodule* in the open bay. The SAV Indicator and components are used to monitor and assess the success of the MFL rule and assess how violations of the rule affect the SAV resource that may trigger requirement of an MFL recovery strategy (Strazisar et al. 2013b). CERP and CEPP evaluations of restoration strategies use the SAV Indicator in evaluating potential management strategies and performance targets. The indicators continue to be integrated into the Florida Bay Seagrass Ecosystem and Assessment and Community Organization Model (SEACOM) so that model runs will automatically update stoplight indicators on a basin scale (Madden and McDonald 2010, Madden 2013).

New insights relevant to future restoration decisions

It is known that the gains in the quality of SAV habitat over the past several years are precarious and can be reversed within a short timescale by climatic events. The long-term steady rebound of the SAV community from a massive seagrass die-off in 1987 and a severe algal bloom in the eastern bay in 2005-2008 was reflected in gradually improving status scores in the late 2000's and early 2010's through the relatively wet years of 2012 and 2013 with lower salinities. The drought years that followed in 2014 and 2015 caused a decline in SAV status indicators which, while still impacted, show signs of recovery. Note that the May 2015 survey failed to capture the impact of the seagrass die-off event which began in June. Consequently, supplementary sampling was done in October to capture die-off effects and revise the WY 2016 calculations. By the May survey of WY 2017, some seagrass recovery had already begun. Reduced algal and nutrient concentrations in WY 2019 and WY 2020 and positive trends in some SAV indicators are developing. Water management initiatives that deliver more water to Florida Bay will aid in supporting these trends.

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JUVENILE PINK SHRIMP INDICATOR

Summary/Key Findings

Funding for system-wide sampling was suspended in WY 2012; therefore, no data were available for a full system-wide assessment of the juvenile pink shrimp indicator condition at the end of WY 2020. However, this report provides a view of the status of pink shrimp in WY 2019 and WY 2020 for southern Biscayne Bay, near former FIAN monitoring network sites. Data reported here are from the current 47 sites of the Epifauna component of the Integrated Biscayne Bay Ecological Assessment and Monitoring (IBBEAM) Project of NOAA Fisheries, the National Park Service, and the University of Miami Rosenstiel School of Marine and Atmospheric Science.

- The juvenile pink shrimp is an ecological indicator in south Florida because it is found in all south Florida estuaries and has been shown to be influenced by salinity.
- Laboratory studies have shown growth and survival of young pink shrimp to be significantly related to salinity and temperature.
- Multiyear studies in western Florida Bay and nearshore southwestern Biscayne Bay have shown pink shrimp abundance (as density, aka, number per meter squared no/m²) to be significantly related to salinity.
- In south Florida's bays and estuaries, juvenile pink shrimp form an important link in the food web, feeding on small animals that eat algae and detritus and providing food to many sport fish species, including especially spotted seatrout and gray snapper, as well as wading birds such as the great white heron.
- Adult pink shrimp are the basis of commercial fisheries in south Florida that rival spiny lobster and stone crab fisheries in ex-vessel value, whereas younger pink shrimp support local bait shrimp fisheries and seasonal recreational food fish fisheries.

Time Series of Stop Lights

The Integrated Biscayne Bay Ecological Assessment and Monitoring (IBBEAM) project, part of the CERP RECOVER Monitoring and Assessment Program, monitors the abundance and distribution of pink shrimp and other small forage species in the Biscayne Bay CERP assessment area immediately downstream from CERP's Biscayne Bay Coastal Wetland (BBCW) Project. The assessment area is affected not only by BBCW structures and operations but also by all CERP components that influence the flow of fresh water into the area. IBBEAM sampling is conducted twice annually, dry season and wet season, with a 1 m² throw-trap thrown three times each at 47 sites. Continuous data for pink shrimp abundance are available for Dry Calendar Year (CY) 2005 through Dry CY 2020.

Mean density (no/m²) across the 47 sampling sites varies by season, with higher pink shrimp densities overall in the dry season than the wet season (compare ordinate scales in top and bottom panels of Figure 1). This is the case not only in nearshore Biscayne Bay but was also noted in Florida Bay (Browder and Robblee 2009). Density also varies by year within seasons (Figure 1). The highest mean density in the time series was found in the dry season of 2018, a few months following passage of Hurricane Irma across the Florida Keys and up the southwest Florida coast (Figure 1 top panel). Juvenile pink shrimp density was low immediately following Irma's passage (Figure 1 bottom panel).

JUVENILE PINK SHRIMP INDICATOR

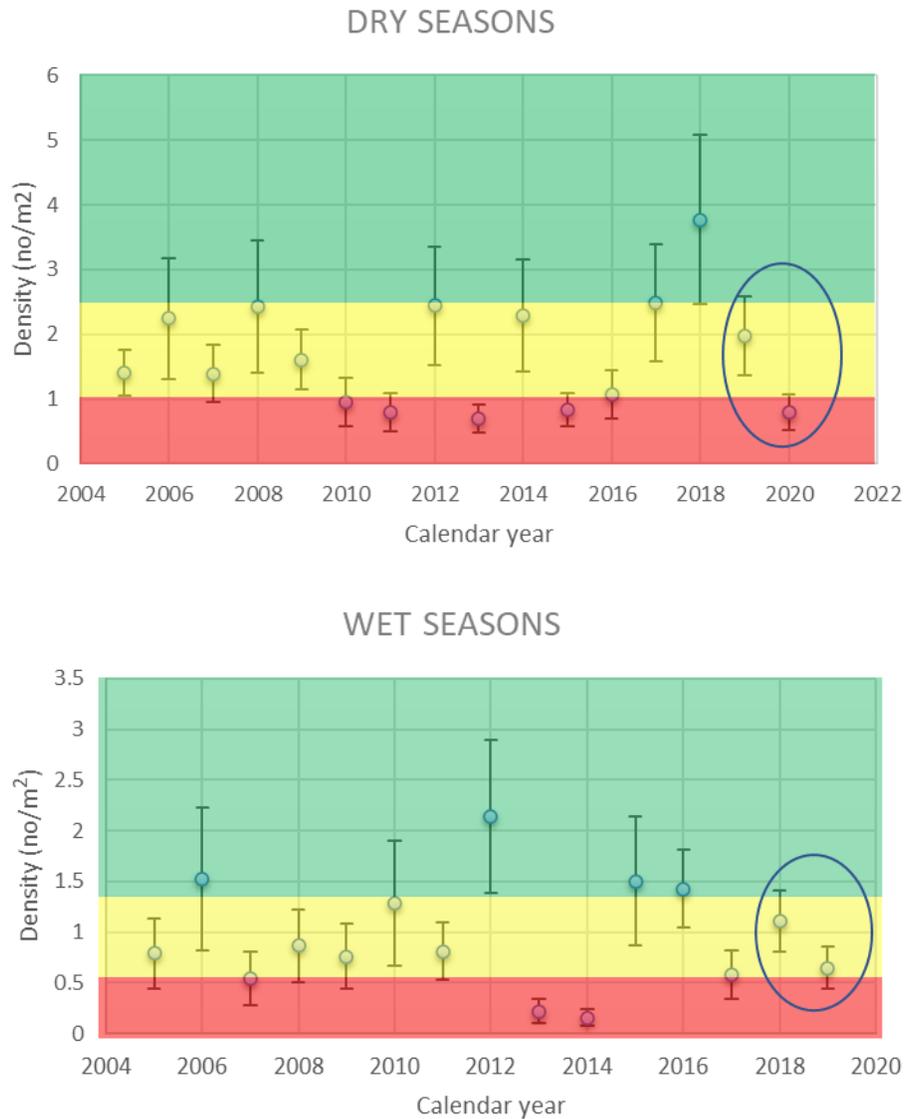


Figure 1. Dry and wet season density of pink shrimp in western nearshore South Biscayne Bay waters, 2005 – 2020, from IBBEAM. Shown are mean values from 47 sampling sites (circles) and their 95% confidence limits (vertical lines). Mean values can be graded as poor, ordinary, or good against the red, yellow and green regions of the graph, respectively, which are separated by the 25th and 75th percentiles of the distribution of abundance values of the previous 14 years (2005-2018 for dry seasons and 2005-2017 for wet seasons).

Against the percentile scale depicted by the three colored regions, abundance status in the CY 2019 dry season can be ranked as ordinary and that of the CY 2020 dry season can be ranked as poor (Figure 1, top). Pink shrimp abundance status can be ranked as ordinary in CY 2018 and CY 2019 wet seasons (Figure 1, bottom).

Stop-light status of pink shrimp abundance (density, no/m²) for the last two calendar years of each season (circled) were graded as poor, ordinary, or good, corresponding to background colors of red, yellow and green, defined by the 25th and 75th percentiles of the distribution of abundance for

JUVENILE PINK SHRIMP INDICATOR

the previous 14 Dry Seasons and 13 Wet Seasons. The 25th, 50th (median) and 75th percentile values for Dry Seasons were 0.99, 1.50, and 2.40, respectively, and for Wet Seasons were 0.57, 0.81, and 1.43, respectively. Mean and 95% confidence values of pink shrimp density used to create Figure 1 are given in tabular form in Table 1, where they are arranged by Calendar Year (CY) and Water Year (WY) for easy reference. In Table 1, means are distinguished as poor, ordinary, or good by color based on their position on the percentile scale. Mean values that fell on the boundary between poor and ordinary (25th percentile) or ordinary and good (75th percentile) were assigned to poor (red) and good (green), respectively (e.g., see CY17 Wet mean value, colored red for poor).

Table 1. Juvenile pink shrimp density (no/m²) in Biscayne Bay (IBBEAM unpublished data).

Water Year	WY13		WY14		WY15		WY16	
Calendar Year	CY13	CY13	CY14	CY14	CY15	CY15	CY16	
Season	Dry	Wet	Dry	Wet	Dry	Wet	Dry	
Lower 95 % CI	0.49	0.10	1.43	0.08	0.58	0.86	0.70	
Mean	0.70	0.22	2.29	0.16	0.84	1.50	1.08	
Upper 95% CI	0.91	0.34	3.15	0.24	1.10	2.14	1.45	

Water Year	WY18		WY19		WY20	
Calendar Year	CY17	CY18	CY18	CY19	CY19	CY20
Season	Wet	Dry	Wet	Dry	Wet	Dry
Lower 95 % CI	0.34	2.46	0.81	1.37	0.44	0.53
Mean	0.57	3.77	1.11	1.98	0.65	0.80
Upper 95% CI	0.81	5.07	1.41	2.59	0.85	1.08

Map of WY 2020 Stop Light Colors

The stoplight area is the nearshore waters of Western Biscayne Bay from Shoal Point to Turkey Point. Individual sampling sites can be classified as having poor, ordinary, or good pink shrimp density (no/m²) in wet and dry seasons of 2018, 2019 and 2019, 2020, respectively, and these classifications are shown in Figure 2 in a stop-light version of a heat map, alongside a map of the monitoring area with sites indicated.

JUVENILE PINK SHRIMP INDICATOR

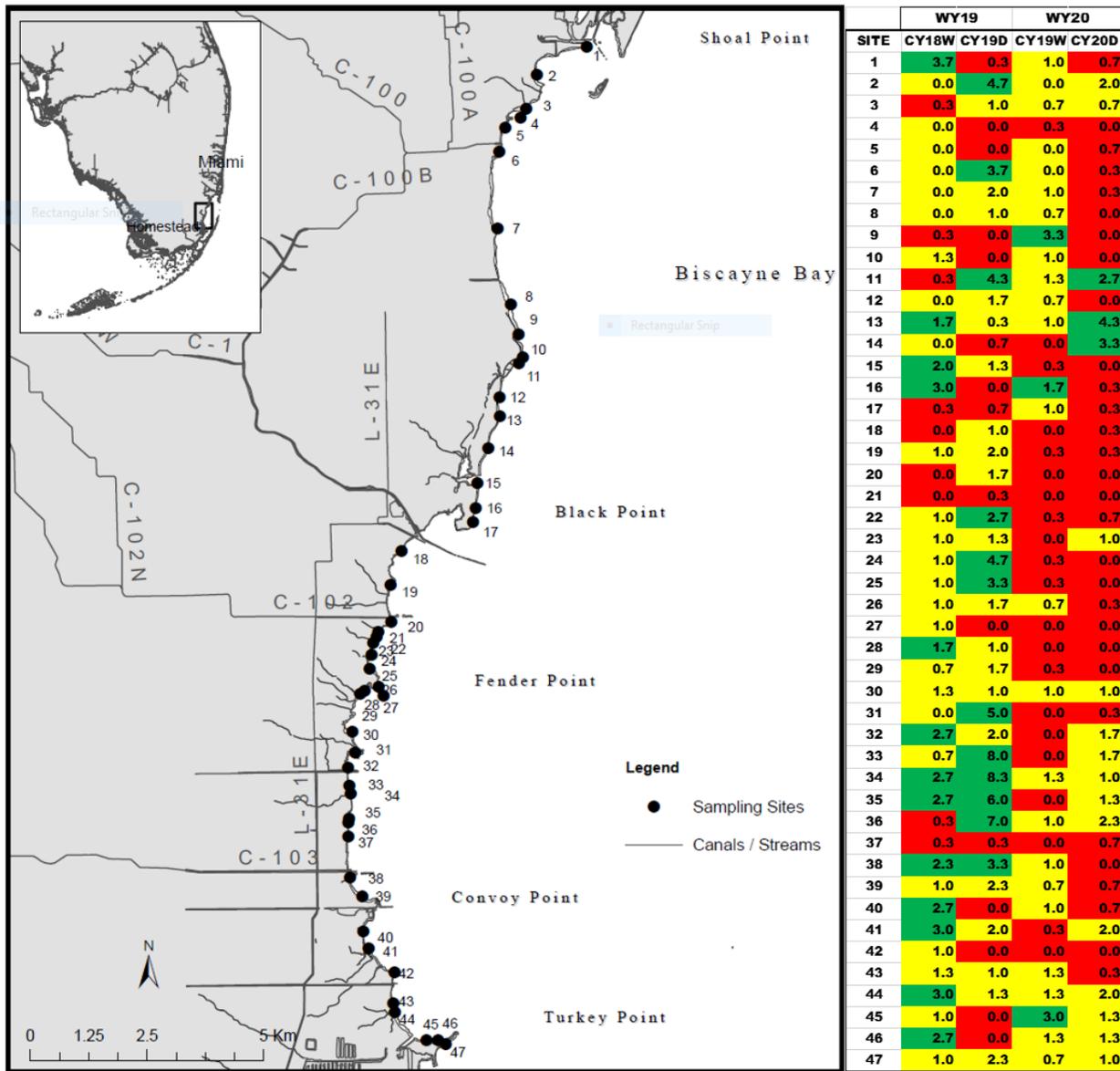


Figure 2. Map of biological monitoring sites of IBBEAM project with stop lights. Coding as poor (red), ordinary (yellow), and good (green) is according to year-season-site pink shrimp density (no/m2) value relative to 25th and 75th percentile boundaries of data from the period CY 2005 through CY 2018.

Interestingly, in each water year, the stoplight site maps for the two seasons are remarkably similar to each other, and the two water years are strikingly different from each other. CY18W and CY 2018D demonstrate a substantial number of green (good) shrimp density sites, whereas CY 2019W and CY 2020D demonstrate many red (poor) shrimp density sites. WY 2020 appears to be a poor year for shrimp throughout the 47-site monitoring and assessment area. As part of future work, it might be useful to extend this stoplight map back in time to previous years for comparison.

JUVENILE PINK SHRIMP INDICATOR

Updates on Calculation of the Indicators

The data in time series presented here differ from those presented in previous reports through 2012 by being based on IBBEAM data from Biscayne Bay. Each dry and wet season data point for each year represents the mean density value (no/m²) from 47 nearshore stations, each sampled with three throws of a 1 m² throw trap to cover a combined 3 m² (Lirman et al. 2020). Used in spotlight reports on pink shrimp prior to 2012, FIAN data were from 19 locations in Florida Bay, Biscayne Bay, and southwest coast mangrove estuaries. Each location was represented by the mean of 30 1 m² throw-trap samples collected on a tessellated grid (Robblee et al. 2014). The Biscayne Bay pink shrimp data presented here represent all the penaeid shrimp collected, including those too small to be identified to species. Because almost all shrimp from this area that have been identified to species are *Farfantepenaeus duorarum* and this is a pink shrimp nursery ground, it is likely that the smaller shrimp identified only to genus or family are *F. duorarum*.

This year's determination of the boundary between poor and ordinary differed from previous years of calculations with Biscayne Bay data. Previously, the boundary between poor and ordinary was the 50th percentile (median). In this year's analysis, the boundary between poor and ordinary is the 25th percentile. Because of this change, the boundary values have been calculated based on data back to CY 2013 (but excluding the last two years available for each season, which are considered the subject years of this assessment). All values from CY 2013 through CY 2019 for wet season, and CY 2020 for dry season are shown on the plots and table. The change from previous years in boundary between poor and ordinary has resulted in fewer years being classified as poor and more years being classified as ordinary than would have occurred with the previous boundary criterion. There was no conceptual change to the boundary between ordinary and good, and so these classifications would only change if the boundary values changed, which might have occurred with the use of more years of data, especially considering inclusion of the exceptionally high density value of CY 2018 Dry, the dry season following Hurricane Irma. Interestingly, there were three poor dry seasons, including one assessment dry season (CY 2020 Dry), and three poor wet seasons (none in an assessment year) in the data series. There was only one good dry season (CY 2018 Dry) and one good wet season (CY 2015 Wet) in the data series, none in the two assessment years. All other wet and dry seasons, including both assessment wet seasons and the remaining assessment dry season, scored "ordinary".

How are these data being used?

Pink shrimp density is being used as one of several species-based indices of nearshore Biscayne Bay ecosystem status in the IBBEAM project. Time series are updated each year in plots and simple analyses to identify seasonal variation, possible responses to extreme events, and short-term and long-term trends. Extreme events that have occurred in the period covered by IBBEAM analyses include the 2010 cold snap, the 2013 algal bloom, hypersaline periods in 2011 and 2015, Hurricane Irma in 2017 and intrusion of sargassum weed in 2015 and 2018. Interestingly, pink shrimp abundance was only mildly affected by Hurricane Irma, which occurred a couple of weeks before sampling (CY 2017 Wet) but experienced a rebound to its greatest recorded value in the following dry season, CY 2018 Dry.

Pink shrimp density data also are being used along with site salinity data to define a relationship between shrimp abundance and salinity for the Biscayne Bay nearshore area. This effort has produced habitat suitability models that can be used in simulating scenarios for hypothesis testing, gaging the potential effectiveness of proposed restoration actions, and informing adaptive management. An ordinary least squares regression model for pink shrimp is updated by IBBEAM from site data for each year and season (Lirman et al. 2020), building on a dataset that is stronger

JUVENILE PINK SHRIMP INDICATOR

and more representative of conditions in the monitored area each year. The model of pink shrimp density in relation to salinity is parabolic with a salinity optimum of 22 ppt. This is within the range reported by other studies reviewed in Zink et al. (2017); also see Zink (2017). Recent analyses using quantile regression to define limiting factors and their influence have produced other results with versions of this dataset (Zink et al. 2018, Zink et al. in review).

New Insights Relevant to Future Restoration Decisions

Data and insights from IBBEAM are being used to evaluate the influence of BBCW structures and their operations on downstream nearshore areas of the bay. The Mesohaline Index prepared from continuously recorded data at two locations downstream from the Deering Estate has been applied to evaluating operations since 2013. Exchanges of observations and data with environmental staff at the Deering site may have led to the recent decision, implemented in September, 2018, to replace pulsed (12 hr-on-12 hr off) pumping at S-700 with continuous pumping of at least 25 cfs of fresh water into the flow-way system (and higher pumping rates whenever additional water is available).

In 2020 IBBEAM started testing and refining an epifauna community indicator for use in nearshore bay waters at the Deering Estate site, recognizing that a salinity indicator alone is insufficient to guide restoration toward an estuarine ecosystem. This need is illustrated by the lack of appreciable numbers of species with affinity for mesohaline conditions at the biological sampling sites where the IBBEAM Mesohaline Index indicates that mesohaline conditions most frequently occur. The pink shrimp is a prominent member of the epifauna community because of relative abundance, frequency of occurrence, and relationship with salinity.

The broad distribution of IBBEAM sites along the shoreline will enable representation of salinity conditions and biological community status to be determined for the overall nearshore area, as well as downstream from each of the BBCW structures. Information and perspective acquired will be used to inform project staff and RECOVER on the effects of restoration actions.

JUVENILE PINK SHRIMP INDICATOR

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WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

Summary/Key Findings

STATUS	PREVIOUSLY REPORTED WATER YEAR 2018	WATER YEAR 2019	CURRENT WATER YEAR 2020
SYSTEM-WIDE	R	R	R

- Roseate Spoonbill foraging and nesting are directly correlated to hydrology and prey availability. Several water management practices, including those that altered hydroperiods, reduced freshwater flow, and made the coastal mangrove zone north of Florida Bay much more saline, resulted in reduced productivity of spoonbill prey that ultimately led to major declines in nesting activity.
- Restoration activities designed to restore the proper quantity, timing, and distribution throughout the Everglades should stabilize hydroperiods, reduce salinity, increase prey productivity, and result in greater nesting success and increased nesting activity of Roseate Spoonbills.
- Everglades Restoration projects that will result in these desired affects are C-111 Spreader Canal Phase 2 (BBSEER), Combined Operations Plan (COP), implementation of Modified Water Deliveries Project (Mod Waters) and CEPP.
- Phase 1 of the C-111 Spreader Canal was completed in 2012 and has shown some evidence of achieving restoration goals by increasing flows to Florida Bay through Taylor Slough and marginally lowering salinity. The C-111 project does not, however, seem to be operated in such a way as to improve conditions in either very low or very high rainfall periods and may actually exacerbate these extreme conditions.
- Spoonbills appear to be responding positively, albeit incrementally, to Everglades Restoration efforts designed to improve conditions in Florida Bay and were scored red (well below restoration target) in both 2019 and 2020. Prey appear to have slightly increased productivity and several spoonbill nesting success sub-metrics responded well enough to be scored as green; however, the number of spoonbill nests have remained very far below targets, indicating that spoonbill chicks hatched in Florida Bay are not finding foraging conditions suitable for them to return as adults to establish nesting.

The Roseate Spoonbill indicator is well below restoration targets; however, it is showing some improvement.

Overall, the stoplight color for the wading bird (Roseate Spoonbills) indicator remains red for WY 2020, although the WY 2020 nesting production and nesting success metrics continue to indicate that conditions throughout Florida Bay appear to be somewhat improving for spoonbills. For the last 7 years, the overall stoplight score has been just below the threshold for being scored as yellow (Table 1). The following metrics were calculated based on those published by Lorenz et al. (2009) with some calculations revised as per the WY 2018 Stoplight Report.

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

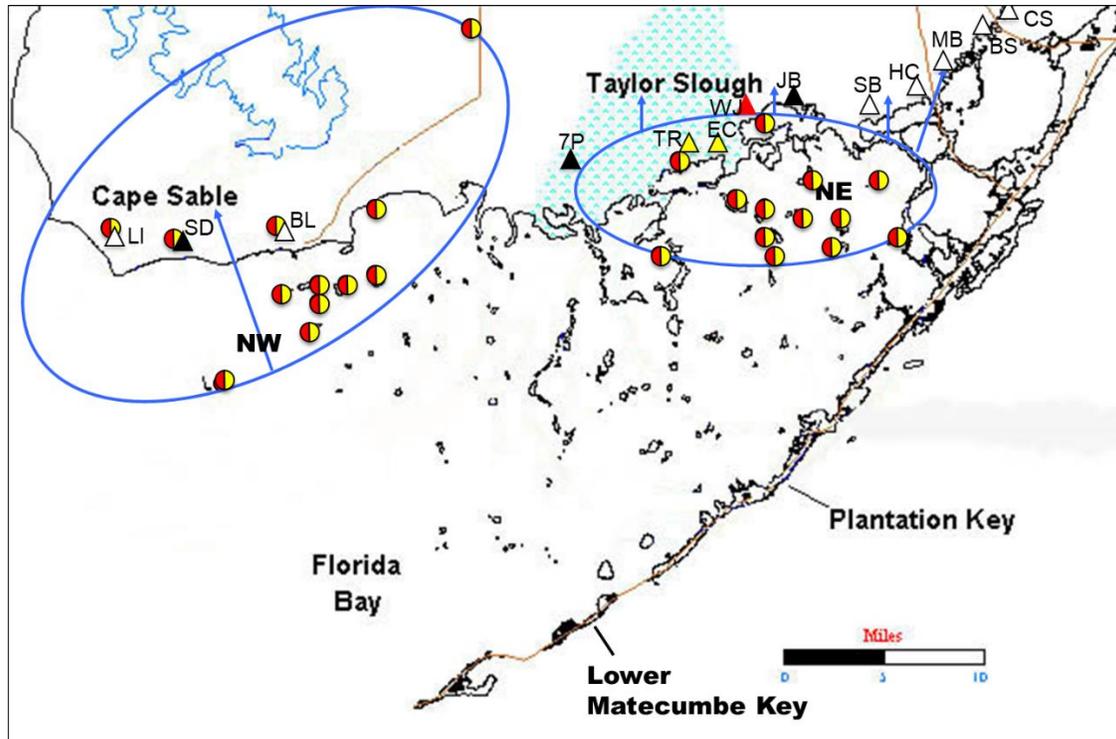


Figure 2. Map of northern Florida Bay showing approximate spoonbill nesting locations (circles) in both the northeastern and northwestern regions of Florida Bay as well as prey base sampling locations (triangles) on their foraging grounds. The triangle color represents the prey score of the mangrove prey base fish metric at each sampling location with the black triangles indicating that data was unavailable for this site and white triangles indicating fish sampling sites that were not used in calculation the metric. The two letter name of each fish collection site is provided next to each triangle. Right half of each circle represents the 2020 score for the nest number sub-metric and the left half of each circle represents the 2020 score for the nest production sub-metric within each region.

Spoonbills were largely extirpated in Florida prior to 1900 due to excessive hunting for the millinery trade. In 1935, spoonbill nesting activity was found on Bottle Key in southern Florida Bay and have since expanded in number concentrating nesting in northeastern and northwestern Florida Bay (Figure 1). Although spoonbills nest throughout Florida Bay, nesting became most concentrated in the northeastern region of the Bay beginning in about 1960 (Figures 1 and 2). Birds nesting in this region concentrate their foraging in the dwarf mangrove forests that line the mainland coast from Taylor River to Card Sound. Nest numbers in this region began to decline in the mid-1980's (Figure 2) following the completion of a set of canals and water control structures known as the South Dade Conveyance System (SDCS) in 1984. The SDCS has been shown to have negatively altered Florida Bay both physically and ecologically (McIver et al. 1994, Lorenz 2014a). Spoonbills also began concentrating nesting in the northwestern region of Florida Bay in the 1970's (Figure 2), with a steady increase in numbers that coincided with the declining numbers in the northeastern region in the 1980's. However, numbers in the northwestern region also began to decline in the mid-2000's (Figure 2).

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

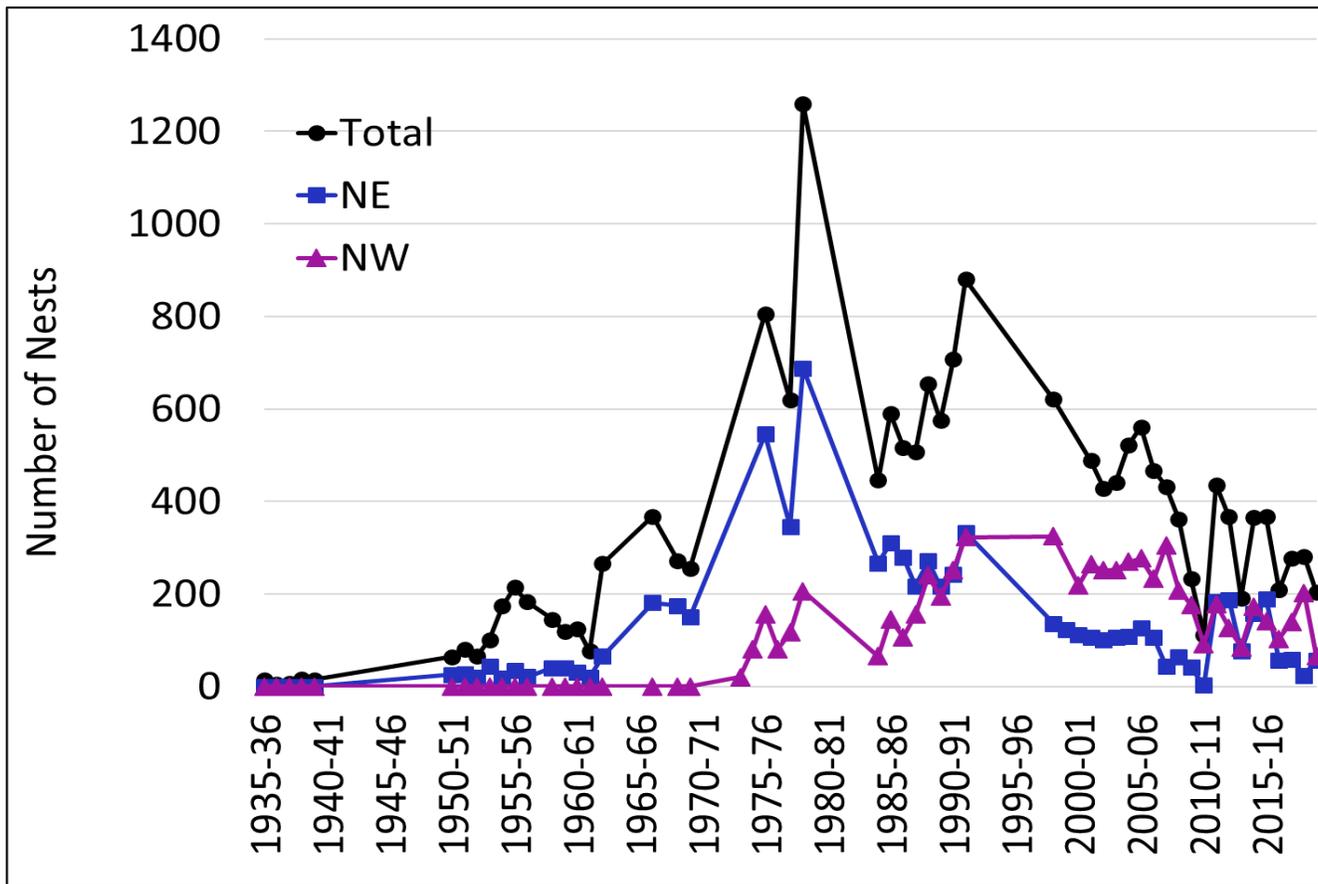


Figure 3. Number of roseate spoonbill nests in Florida Bay and for the Northeastern and Northwestern regions of Florida Bay from WY 1936 to WY 2020.

The indicator sub-metrics for spoonbills are: total nest numbers for all Florida Bay, as well as the number of nests in both the northeastern and northwestern nesting regions, the nest production and success in both regions and the prey fish community structure at foraging sites for birds nesting in the northeastern region. The target for total spoonbill nests is 1258, the highest number of nests prior to completion of the SDCS. This sub-metric is the average from the previous five years expressed as a percentage of 1258 (Table 1). All years from the WY2 014 nesting cycle through WY 2020 ranged from 21% (WY 2020) to 27% and show no trend in response to ongoing restoration projects that affect Florida Bay. The sub-metric for the number of nests in northeastern Florida Bay is the five-year average expressed as a percentage of 688 nests (the maximum number of nests recorded prior to SDCS completion). This sub-metric was even less encouraging than the total nests in Florida Bay ranging from between 11% (WY 2020) to 23% and show no change in trend in response to completion and operation of the C-111 Spreading Canal Western Phase (C-111 SCWP) CERP project in 2012. The C-111 SCWP project was designed to increase flows through Taylor Slough but certain operation that were part of the design structure for the C-111 SCWP have not been implemented (i.e., raising the canal stages at the S-18C structure and minimizing flows to tide through the S-197 structure) and the restoration benefits of the project have not been fully realized, however some beneficial responses have been documented (see nesting success and production, and prey community structure below sub-metrics). The sub-

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

metric for the number of nests in the northwest region is also expressed as a percentage but is based on the minimum, maximum and mean of the number of nests found in the northwest region at the time the sub-metrics were established. Compared to bay-wide and northeastern region nest numbers, the northwestern region seems to be performing better but is still very far below the target. There is no clear trend either up or down in this sub-metric and for the last 7 years has fluctuated just at the threshold between yellow and red scores.

Table 1. Stoplight scores for each sub-metric, the cumulative score for each sub-metric and the overall score for the indicator for the last five years. Scores are in percentages of restoration with 0% representing a system unaffected by restoration efforts and 100% being fully restored. Scores assigned a green if the average score of the 4 parameters was ≥ 67 , yellow for 34-66 and red for ≤ 33 .

Year	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
Total Nests in Florida Bay	21	23	27	24	22	24	21
Number of Nests in NE Florida Bay	14	18	23	19	16	14	11
Number of Nests in NW Florida Bay	34	34	38	32	32.9	42	33.4
NE Production and Success	45	53	37	39	34	40	36
NW Production and Success	34	46	60	60	60	50	50
Percent Freshwater Prey Species	50	5	2	25	20	25	27*
Overall¹ Spoonbill Nesting Score	33.1	30	31	33.2	31	32	30

¹ Overall stoplight score is the numerical average of the 5 sub-metrics.

Nest production is the average number of chicks produced per nest attempt (c/n) for a given year. The sub-metric is the five year mean of these estimates and is expressed as a percentage of several thresholds (0-0.7c/n is a declining population, 0.7 to 1.0 is stable, and >1.0c/n is an increasing population. 1.38c/n was the average production prior to completion of SDCS). The nesting success sub-metric is simply the percentage of the last 10 years that spoonbills nested successfully (i.e., produced 1.0c/n or more on average). For each region, the lower of the two scores is the nest production and success sub-metric. In the northeast, the nest production sub-metric was relatively high in WY 2014 and WY 2015 but was near the yellow/red threshold in WY 2020 (36%; Table 2). In spite of this, spoonbills have nested successfully (>1c/n) 70 to 80% for the decade previous to each water year scored (Table 2). The overall sub-metric score for the northeast region is therefore the same as the nest production score (Table 2). In contrast to the northeastern region; spoonbill production in the northwestern region has greatly improved in recent years with a steady increase from 34% in 2013-14 and has been scored green since WY 2016 (Table 2). In WY 2019, the restoration target was actually met (score >100%). The nesting success sub-metric dropped from 60% prior to WY 2019 to 50% the last two years (Table 2). Therefore, the nest production and success sub-metric for the northwest was the nest success sub-metric for all years, except for 2013-14 and 2014-15 when the nest production sub-metric was lower than the success sub-metric (Table 2). The nest production and nesting success sub-metrics for both the northeast and northwest regions were yellow for all seven years which can be considered a positive response when considering that the 2012 Stoplight Report indicated a downward trend at that time.

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

Table 2. Nest production and nesting success sub-metrics by nesting sub-region of Florida Bay. The nest production sub-metric the five year average nest production (c/n) and is expressed as a percentage of the target (1.38c/n). The nesting success is the number of years out of the last 10 that spoonbills produced >1c/n expressed as a percentage. The combined sub-metric is lower of the two sub-metrics. Scores assigned a green if the average score of the 4 parameters was >66, yellow for 33-66 and red for <33.

Year	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
Nest Production Northeast	45	53	37	39	39	40	36
Nesting Success Northeast	70	80	80	80	80	70	70
NE Production and Success	45	53	37	39	39	40	36
Nest Production Northwest	34	46	73	88	79	100	87
Nesting Success Northwest	60	60	60	60	60	50	50
NW Production and Success	34	46	60	60	60	50	50

Prey fish communities at 11 historic spoonbill foraging sites within the mangrove transition have been quantified from primary foraging locations of wading birds (including spoonbills) nesting in Florida Bay (Figure 1). We quantified the prey community at four of these sites that were associated with Taylor Slough and the C-111 basin. The calculation of this metric has changed from previous reports (see below) explaining the need to recalculate the stoplight metrics going back to WY 2014 throughout this report. The prey community structure is simply the percentage of the fish prey base that are classified as freshwater species at each site (Lorenz and Serafy 2006). This is based on the finding that prey are more abundant and have higher biomass when a significant component of all prey base fishes are freshwater species (Lorenz and Serafy 2006). Simply stated; prey productivity is greater at lower salinity and the presence of freshwater species is representative of that increased production. The target is to have at least 40% of all prey fish be classified as freshwater based on the findings of Lorenz and Serafy (2006) with a percentage of higher than 5% indicating a positive response to restoration efforts. Results for the 7 year period from the WY 2014 to WY 2020 are presented in Table 3. The only year above the 5% threshold was WY 2014, however, it appears that for the last 4 years there has been consistent representation of freshwater species within our samples. An examination of the percent catch at individual sites also indicates that freshwater fish representation has increased at sites more centrally located in Taylor Slough (Table 4). One goal of the C-111 Spreader Canal Western Phase (C-111 SCWP) was to increase freshwater flow through Taylor Slough and it appears from this metric that conditions that support freshwater fish species are becoming more persistent at sites located within the Slough. This is a promising finding even if the overall sub-metric still remains in the red.

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

Table 3 Prey fish sub-metric as previously but erroneously reported in the 2018 report. The sub-metric is based on the percent catch of species from sampling sites (Figure 1) classified as freshwater species with <5% scored red, ≤5% to <40% scored yellow and ≤40% scored green. To match the other sub-metrics, the percentage catch was converted from the 0-40 scale to a 0 to 100 scale to make up the stoplight score with >66 scored green, 33-66 yellow and <33 red.

Year	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
Percent freshwater species previously reported	17.08	0.44	0.35	2.21			
Stoplight Score as previously calculated	40	2	1	9			

Table 4. Corrected prey fish sub-metric as recalculated in this report (see Updates on Calculations of Indicator section). The sub-metric is based on the percent catch of species from sampling sites (Figure 1) classified as freshwater species with <5% scored red, ≤5% to <40% scored yellow and ≤40% scored green. To match the other sub-metrics, the percentage catch was converted from the 0-40 scale to a 0 to 100 scale to make up the stoplight score with >66 scored green 33-66 yellow and <33 red.

Year	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
Percent freshwater species updated calculation	22.98	0.76	0.34	3.63	2.98	3.68	3.98*
Stoplight Score updated calculation	50	5	2	25	20	25	27*

*only 3 of the four sites were used to calculate WY2020 because data was not yet available for the JB site at the time of writing

Table 5. Percent catch of freshwater fish species for each of four sampling locations WY 2014 to WY 2020.

Year	WY 2014	WY 2015	WY 2016	WY 2017	WY 2018	WY 2019	WY 2020
TR	33.88	1.74	1.06	3.76	5.22	8.21	5.99
EC	36.66	1.08	0.00	8.84	1.73	2.56	5.54
WJ	17.02	0.00	0.18	2.24	1.38	1.72	0.42
JB	4.36	0.23	0.12	0.41	2.61	1.68	

The overall spoonbill stoplight score is calculated as the average of the individual indicator sub-metrics. Because all metrics are on a 0-100 scale this can be expressed as the percentage of ecosystem functionality of a restored system. The overall spoonbill restoration metric went down from 30% to 28% indicating that the ecosystem is only functioning at about a quarter of its historic capacity. However, it is promising that since the completion of the C-111SCWP, the score consistently is near the red/yellow threshold as compared to before project completion when the scores were even lower. The Combined Operational Plan which includes operations of the newly completed Modified Water Deliveries Project, will be implemented later in 2020 and should further augment freshwater flow to Florida Bay and hopefully will sustainably push the indicator score into the yellow but is unlikely to accomplish green status due other constraints (see Insights section below).

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

Updates on calculation of indicator

Prey Base Fish Metric

The Stoplight metric as published (Lorenz et al. 2009) was developed on data collections made prior to 2006. Since that time several changes unrelated to restoration efforts have made calculating the prey fish sub-metric more problematic. As specified in the 2009 publication this metric was based on calculating the percent catch of freshwater species from seven collection sites located in the Taylor Slough C-111 watersheds. As previously reported, one of these sites (7P) was defunded as part of RECOVER in 2011. This site was located in a freshwater dwarf mangrove habitat just north of Seven Palm Lake (Figure 1) and had the highest percentage of freshwater fish species of all the sampling sites. When the sub-metric was created in 2009, this site was integral to interpreting the results and was accounted for when setting the targets. Losing this site means that the highest FW site is no longer included in the calculation, therefore, the sub-metric will be lower because of the loss of the site not because of changes in the ecosystem. The two most eastern sites north of Florida Bay (SB and HC) have also become problematic due to issues related to the reconstruction of US Highway 1 (US1) from the mainland to the Keys in 2008 and also due to the recent exponential increase in sea surface elevation. Prior to reconstruction of US1, there was virtually no hydrologic link between Barnes Sound (in southern Biscayne Bay) and Long Sound in extreme northeastern Florida Bay (where SB and HC are located). During the reconstruction, tidal flow through Manatee Creek (the boundary between Dade and Monroe counties) and several smaller creek to its north was restored. Prior to construction of the East Coast Railroad (which later become the roadbed for US1) in 1904 Manatee creek was a major flow way between Barnes Sound and Card Sound and flows were further augmented by the small creeks to the north. The restoration of this historic hydrologic connection between the two Sounds was expected to allow freshwater to flow from Everglades National Park on the western side of US1 to the east into Barnes Sounds as it did historically. What wasn't anticipated was that sea surface elevations are now more than 0.25m higher than they were prior to the railroad's construction back in 1904 (Figure 3). Furthermore, Barnes Sound has a significant diurnal tide and historically Long Sound did not. As a result of flow restoration; Manatee Creek has become a major tidal flow way, and Long Sound is now experiencing a significant diurnal tide. This has significantly changed the habitat at the SB and HC sites by making them increasingly salty. Not only did this reduce the number of freshwater fishes at these two sites, but the tidal action alone altered the fish community using these sites. These dramatic physical changes to these sites unrelated to Everglades restoration efforts makes these two sites also unsuitable to use in calculating the fish sub-metric as it was proposed in 2009. Therefore, we now only use four sites (TR, EC, WJ and JB) to calculate the prey fish sub-metric.

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

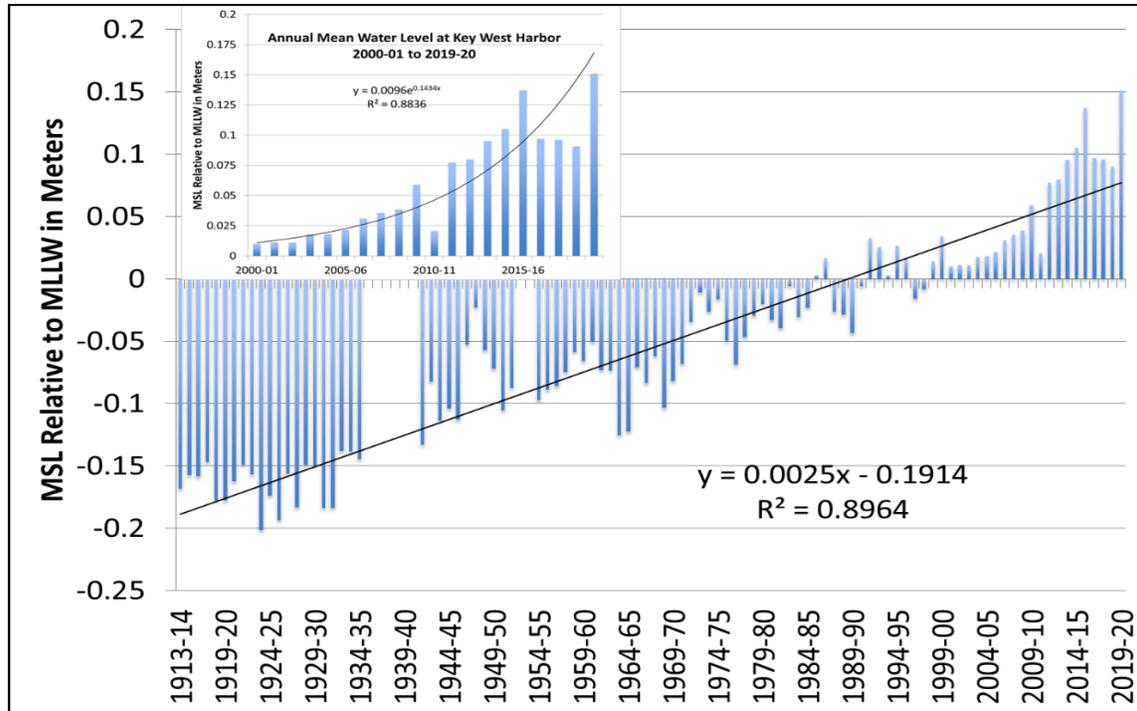


Figure 3. Mean sea level in relation to Mean Low Low Water for Key West Harbor 1913 to present. Inset is the same data from 2000 to present indicating an exponential increase in sea level rise as predicted by many climatologists.

Lorenz (2014b) showed that prey fish utilizing the ephemeral wetlands are forced into permanently wetted creek habitat when water level on the wetlands drops below about 13.5 cm. This results in high concentrations of prey fish in the creeks that are exploited by higher trophic levels such as Roseate Spoonbills and is known as the Prey Concentration Threshold, or PCT. Prior to 2009 the number of days water levels were below the PCT at our sites was generally between 100-150 days (Figure 4). Due to higher sea surface elevations (Figure 3) the number of days below the PCT has been reduced to less than 50 days (Figure 4). This not only reduces the number of samples collected where the sites are experiencing a prey concentration event but makes the probability of capturing an event at only one site more likely thereby biasing the sub-metric toward the fish community at that site. Using WY 2020 as an example, the total number of fish collected in all samples was 1660 at WJ, 951 at TR and 794 at EC. We did sample during a concentration event at WJ but not at either TR or EC thereby explaining the much higher total at WJ. If we simply took the total number of freshwater fish collected at these sites (108) and divided by the total number of fish collected (3405) the result is 3.1% freshwater catch, however, this result is heavily biased toward the community structure that occurred at WJ. If we were still using the seven sites for this metric, the sheer number of samples collected would have provided a buffer against this bias. For this reason, we now calculate the percent freshwater catch for each site and then take the average of those percentages (4.0%). Although this seems like only a slight change in this case, it could be very significant in other circumstances. For example, since we could not include the WY 2020 data from JB at this time, the results from that site may easily result in change from our current score of red to yellow if the JB numbers are more reflective of TR and EC than WJ (Table 4).

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

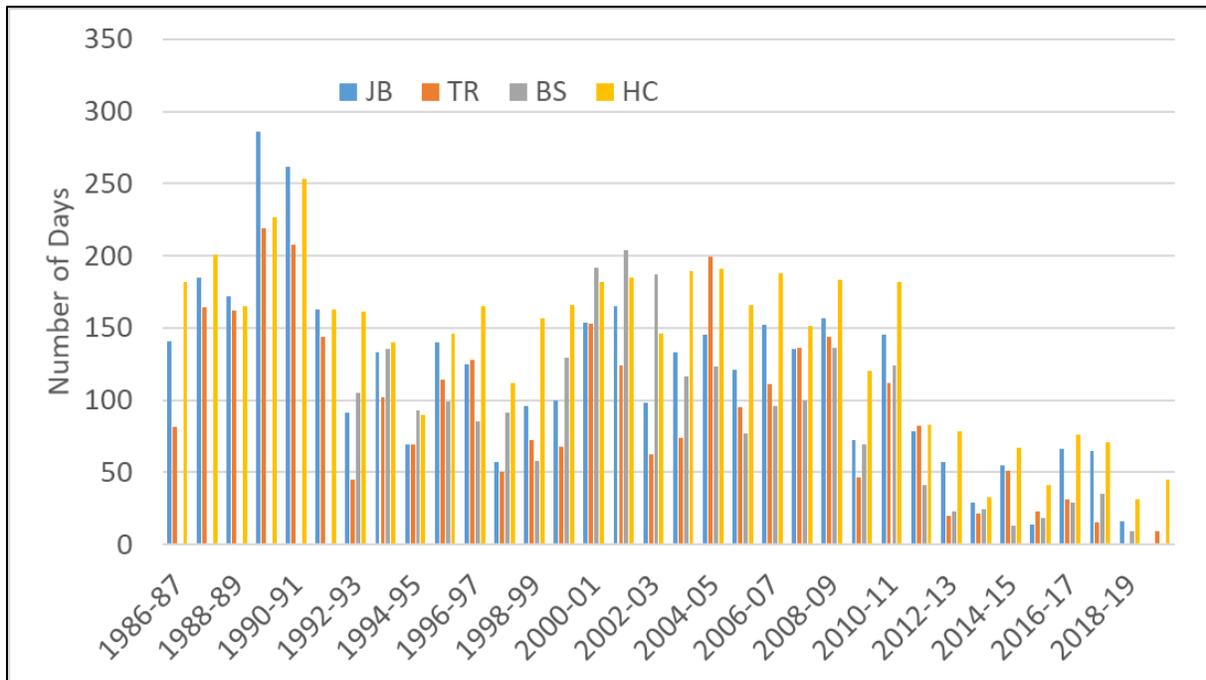


Figure 4. Number of days each hydrologic year that water levels were below the prey concentration threshold (13.5cm relative depth; Lorenz 2014B). Note: data collection did not begin at BS until 1992-93; data were unviable at this time for JB and BS in 2019-20; there were no days below the PCT at TR in 2018-19.

The last change to the prey base fish sub-metric was simply to correct a mistake we made in 2018 update of this sub-metric when placing it on a 0-100 scale. Table 5 shows the proposed equations from the 2018 update. It places the 0-5% catch of freshwater fishes on 0-20 scale. Lorenz et al. (2009) set the threshold between red and yellow scores at 5% catch of freshwater species. Since all other metrics on the 0-100 scale place the red/yellow threshold at 33.3% the prey fish metric needs to be on that scale as well. Similarly, the yellow/green threshold should be placed at 66.6% rather than proposed 80% from the 2018 update. Table 6 presents the equations that place this sub-metric on the proper 0-100 scale.

Table 6. Incorrect restoration grading calculations for the Mangrove Prey Base Fishes Stoplight from the 2018 update.

Percent Freshwater	Restoration Grade Percentage Range	Equation
0-5%	0 - 20	$y = 4x$
>5-40%	20 - 80	$y = 1.6857x + 11.571$
>40%	80 - 100	$y = 0.35x + 65$

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

Table 7. Restoration grading calculations for the Mangrove Prey Base Fishes Stoplight to correct the mistake made in the 2018 update.

Percent Freshwater	Restoration Grade Percentage Range	Equation
0-5%	0 - 33.3	$y = 6.66x$
>5-40%	33.34 - 66.6	$y = 0.9523x + 28.569$
>40%	66.67 - 100	$y = 0.5556x + 44.441$

Northwestern Nest Number sub-metric

Similarly to the prey fish sub-metric, there was a mistake in how the northwestern nest number sub-metric was placed on a 0-100 scale in 2018 update. Lorenz et al. (2009) placed the threshold between a red and yellow score at 130 nests and the threshold between yellow and green at 210 nests. The 2018 update erroneously used calculation that placed 130 nests at the 20% scale and 210 nests at 60%. These should have been 33.33% and 66.66% respectively to reflect the original scoring in Lorenz et al. 2009. Table 7 presents the incorrect calculations from the 2018 update and Table 8 presents the corrected calculations.

Table 8. Incorrect restoration grading calculations for the northwestern nest number stoplight from the 2018 update.

Number nests	Restoration Grade Percentage Range	Equation
0-130	0-20	$y = 0.1538x$
130-170	20-40	$y = 0.4878x - 43.415$
170-210	40-60	$y = 0.5128x - 47.692$
210-324	60-80	$y = 0.1754x + 23.158$
>=325	80-100	$y = 0.1754x + 23.158$

Table 9. Restoration grading calculations for the Mangrove Prey Base Fishes Stoplight to correct the mistake made in the 2018 update.

NW Nest Number	Restoration Grade Percentage Range	Equation
0-130 nests	0 - 33.3	$y = 0.2564x$
>130-210 nests	33.34 - 66.6	$y = 0.4170x - 20.914$
>210-324 Nests	66.67 - 100	$y = 0.2926x + 5.189$

How have these data been used?

Data from this monitoring program was used to evaluate overall wading bird health in southern Florida through the annual South Florida Wading Bird report for 2019 and 2020. However, neither of these reports has been released at the time of this writing because of delays created by the existing Covid-19 pandemic. Likewise, the data was compiled for the South Florida Environmental Report but the 2020 report is not yet available. Annual reports to the US Army Corps of Engineers, the South Florida Water Management District and Everglades National Park analyzed these data as well.

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

New insights relevant to future restoration decisions

It is time to revisit how this indicator is calculated based on the issues describe above and elaborated on further below.

Effect of sea level rise on indicator.

As indicated above, sea level rise has a significant impact on water levels in the spoonbills' foraging habitats north of Florida Bay (Lorenz et al. 2011), and the lack of concentration events appears to be having a profound effect of spoonbill nesting activity, especially nest initiation date. For example, Alvear-Rodriguez (2001) estimated spoonbill nest initiation dates (defined here as the first egg laid) in Northeastern Florida Bay for 51 years between 1936 and 2000 from field notes collected by various researchers. Nest initiation occurred between Nov 1 and Dec 31 in all years except 2 (one in late Oct and one in early Jan). As part of the South Florida Annual Wading Bird Report we have reported these dates since 2003. From 2003-04 to 2009-10 all initiation dates fell within the range reported by Alvear-Rodriguez (2001). From 2010-11 to 2013-14 all nest initiation dates were between Jan 1 to Jan 10. In 2014-15 the date was Jan 24 and in 2015-16 it was Feb 5. The last two years (WY 2019 and WY 2020) the mean neat initiation date has been Feb 10 and 12 respectively. Later and later nest initiation dates have occurred in all the other regions of the bay as well. Moreover, lay dates within and among colonies were highly asynchronous, spanning January through April. These results suggest that the important environmental cues that prompt breeding were either lacking or weaker than historically. We believe that this is occurring because the birds are delaying breeding activities until fish become concentrated on the foraging grounds, concentration events that are becoming increasingly rare (Figure 4). Also, major nesting events have become common at colonies on the mainland that were never used by spoonbills prior to around 2010. Clearly, however, the production and success sub-metrics are showing that spoonbills that nest in Florida Bay have been more successful at raising young than before sea level rise became an issue around 2010. Preliminary data from a spoonbill tracking program suggests that, although spoonbills still use the mangrove wetlands north of the Florida Bay to forage, they no long use it exclusively and now exploit mangrove wetlands located in the interior of islands in Florida Bay as well. The lack of increased nesting effort in Florida Bay suggests that the Florida Bay nesting population has become a source population for new inland colonies recently established in the interior Everglades. The high success of spoonbills that still nest in Florida Bay suggests that perhaps restoration efforts are having a positive effect on the Florida Bay but the low number of spoonbills choosing to nest in Florida Bay is likely due to high water levels unrelated to restoration efforts.

Unfortunately, the Spoonbills Stoplight metric as published in 2009 relies heavily on nest number with half of the sub-metrics tied to nest counts. It has become increasingly apparent in the last decade that spoonbills are unlikely to nest in the large numbers of the 1970's (Figure 2) even if restoration efforts are completely successful thereby necessitating a complete revision of the stoplight metric. The revised stoplight metric will need to de-emphasize nest number while developing other measurements that better evaluate Everglades restoration efforts. Fortunately, such metrics have been or can be developed based on other analytics, many of which have been developed since the original stoplight was published in 2009. The updated stoplight metric will utilize several physical and biological parameters that have been collected as part of the ongoing Florida Bay spoonbill ecological study. This is not to say that the new metric will ignore sea level rise, rather it will incorporate it into a better understanding of what can be the expected ecosystem responses to restoration efforts given that sea surface elevation will continue to rise. The hope is to publish this new stoplight metric (or at least have a draft completed for submission) by the time of the 2022 report. The following paragraphs detail some initial thoughts on parameters that may be used in the rewriting of the stoplight.

WADING BIRDS (ROSEATE SPOONBILL) INDICATOR

It became apparent shortly after the publication of the stoplight in 2009 that coupling the northeastern and northwestern nesting region into a single overarching metric was problematic. From a restoration standpoint, these two regions represent completely different restoration efforts with the northeastern region most affected by efforts related to Taylor Slough and C-111 Canal, while the northwestern region will be affected by Shark Slough and Cape Sable restoration efforts. In the current design, a positive response in one region can be completely negated by a negative response in the other. The two regions are used to evaluate completely different restoration aspects and need to be decoupled. The update to the spoonbill stoplight will have two completely independent metrics for the northeastern and northwestern regions of Florida Bay. For the purposes of this report, these two metrics would then be averaged for an overall spoonbill stoplight score.

The sub-metric for total nests in Florida Bay will be removed. For the northeastern region we propose keeping nest number as a sub-metric but changing the target to the maximum multi-year average number of nests that occurred prior to the construction of SDCS rather than the single highest year. Since this metric uses a five year average so should the target. Furthermore, this sub-metric will be deemphasized by having 5 additional equally weighted sub-metrics rather than have nest number count for half of the total stoplight score. Although this target is not expected to be reached through restoration efforts, it is necessary to keep this metric to account for the expected shortfall in the full restoration of ecosystem function caused by sea level rise. The current productivity and success sub-metric will be divided into two standalone sub-metrics rather than be merged into one. Currently, the lower of the two is used to calculate the overall metric. The 2009 publication combined the two because both sub-metrics are calculated from the same raw data set, however, each evaluates different important aspects of spoonbill population dynamics. Productivity is based on the number of chicks produced per year using the 5 year mean. This numerically tells how many spoonbill chicks were produced in a five year period and can be high regardless if only one or two years had very high productivity while the other 3 or 4 were complete failures or if all five years were moderately successful. The success sub-metric evaluates how consistent Florida Bay provides the ecosystem services required for spoonbills to raise young by measuring how many times spoonbills produced 1c/n on a decadal scale. The efficacy of using both as independent sub-metrics rather than the lowest can be best understood by using an example from Table 2. In WY 2019, the restoration target for the nest production in the northwest region was exceeded (>100%) but the combined score was only 50% because the success metric was the lower of the two. Taking the lower of the two completely discounts that spoonbills were highly productive from WY 2015 through WY 2019 because they averaged only 0.9c/n in both WY 2011 and WY 2012 and 0.8c/n in WY 2019 and WY 2020. Technically these are considered failed years because they did not produce 1.0c/n, however by using only the measure for consistency, the fact four of the years were borderline and five of the remaining 6 years had very high production values is lost. If both were used, the metric would take into account that Florida Bay was inconsistent in providing the necessary ecosystem services in the northwestern region but, when those services were provided, they were much higher than the minimum requirement. By having both as standalone sub-metrics both important aspects of the ecosystem are taken into account.

The prey base fish sub-metric will remain as stated above using only 4 of the actively sampled 11 fish monitoring sites (Figure 1), however, we will endeavor to separate these 11 sites into 4 regions. The 4 regions will be as follows: 1) Little Madeira Bay (LMB) which will include the TR and EC are located directly in Taylor Slough and reflect efforts directly related to the restoration of fresh water flows to Taylor Slough. 2) Joe Bay (abbreviated TC for Trout Cove, located just south of Joe Bay, to distinguish it from the JB site - Joe Bay acts as a repository for freshwater sheet flow and currently provides the largest point source of fresh water flow to Florida Bay

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through Trout Creek into Trout Cove) will include the WJ and JB sites. 3) Long Sound (LS) includes SB and HC, the hydrology of which is described above. 4) Southern Biscayne Bay (SBB) which has 3 sites (MB, BS and CS). These sites are arranged such MB is located immediately to the north of the mouth of C-111 canal and evaluates the impact of discharges through the canal at S-197. BS is located in the area impounded between US1 and Card Sound Road beds currently acts as flow control site (i.e. the impoundments prevent any sheetflow from the Everglades such that the only source of fresh water is from rainfall that occurs directly on the wetland between the two roads) but may have sheet flow restored to it as part of the Biscayne Bay Southeastern Everglades Restoration (BBSEER) Project. CS is located just north of Card Sound Road and currently acts as a further control. This site may also receive restored sheet flow as part of BBSEER depending on water control structure alignment decided upon during project planning. Currently only the LMB and TC regions will be used in the fish metric but we hope to devise a mechanism that the other two regions will be included in the sub-metric if they show a positive response in prey fish community (i.e., a lower salinity community as per Lorenz and Serafy 2006) but will not lower the stoplight if the community remains in its current state. To summarize, the LMB and JB regions will provide the stoplight score but that score can be improved if we document positive fish community changes in either the LS or SBB regions.

Each of the fish sampling sites has a hydrostation that measures salinity, water level and water temperature which were installed sometime between 1990 and 2004 depending on the site. Submerged Aquatic Vegetation (SAV) has also been systematically quantified along a multi-location transect (starts at the site and extends to open water of the estuaries) since 1996. Sub-metrics for both SAV and salinity will be developed based on the long term data trends and restoration expectations. These two sub-metrics will also be assessed along the same regions as the prey base fishes with LMB and TC providing the stoplight score and LS and SBB only contributing to the score if improvements are documented within these two regions.

Developing a set of sub-metrics for the northwestern region of Florida Bay is more problematic the northeastern region. There are only two fish collection sites on Cape Sable (LI and BL); each equipped with a hydrostation but no SAV surveys are performed at these sites. Furthermore, the northeastern sites are all located in dwarf red mangrove forests while Cape Sable is dominated by mature black mangrove forests, and samples are collected in shallow open water areas near the black mangrove forests rather than directly within the forest. The spoonbill nest number and nesting success sub-metrics will be used as has been described in Lorenz et al. (2009) and updated in the 2018 report with the exception that each will be a standalone sub-metric rather than lower of the two (as similarly proposed for the northeast). Fish community dynamics at these sites are completely different than those in the northeast so the findings of Lorenz and Serafy (2006) cannot be applied and neither can the 13.5cm PCT (Lorenz 2014b). Salinity at these sites is much higher and does not approach freshwater conditions (Wingard and Lorenz 2014). Although fish data has been collected at these two since 1990 (BL) and 2005 (LI) the data has been used sparingly (Lorenz et al. 2013). In order to develop sub-metrics and targets for fish and salinity, these data will require analyses that relate fish abundance and availability to salinity, water level or both (as per Lorenz et al. 1999 and Lorenz and Serafy 2006) as well as analyses to find a deterministic relationship between some aspect of fish community dynamics and spoonbill nesting in the northwestern region (as per Lorenz 2014b). Although we will endeavor to investigate these relationships, it is doubtful that they can be fully explored by the time 2022 report so, for now, the stoplight metric for the northwestern region may be based solely on the spoonbill nest number and productivity sub-metrics.

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